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TITLE. THERMAL CONDUCTIVITY OF Q-FELT INSULATION AT ELEVATED TEMPERATURES

MODEL ______ CONTRACT NO. AF 33(615)-1624 BPSN 6365-620A

ISSUE NO.	ISSUED TO

FINAL REPORT

APRIL 1, 1964 TO AUGUST 15, 1964

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PREPARED BY ______ T. W. Eichenberger

SUPERVISED BY ______ O. T. Ritchie

APPROVED BY ______ O. T. Ritchie

APPROVED BY ______ A. K. Hepler

APPROVED BY ______

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PREFACE

The information gained concerning the thermal conductivity of Q-felt micro-quartz fiber insulation material under Contract No. AF33(657)-7132 for the design and development of the X-20 Re-entry Vehicle is reported in this document. This document was prepared under Contract AF33(615)-1624.

ABSTRACT

The thermal conductivity of Q-felt, a commercial micro-quartz fibrous insulation material, was evaluated. Tests were conducted on several densities each of as received and thermally stabilized material at elevated temperatures and at atmospheric and reduced pressures. Mean test temperatures ranged from 200°F to 2560°F and reduced pressures to 0.1 mm/mercury were used.

Curves have been prepared presenting the mean apparent thermal conductivity of both thermally stabilized and unstabilized Q-felt as a function of mean temperature, gas pressure and material density.

Insulation
Q-Felt
Thermal Conductivity
Micro-Quartz Fibers

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1. "Standard Method of Test for Thermal Conductivity of Materials by Means of the Guarded Hot Plate", ASTM C 177-45, American Society for Testing Materials, Philadelphia, 1945.

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NOMENCLATURE

C	Statistical Confidence Limit
k	A statistical factor
K	Thermal conductivity, 10^{-6} BTU-in/sec-in^2-°F
$\bar{K}$	Average Thermal Conductivity, 10^{-6} BTU-in/sec-in^2-°F
n	Number of individual values in a data group
P	Statistical Probability of values falling within the stated limit
Q	Heat flow, 10^{-6} BTU/sec-in^2
t	Specimen Thickness, inches
T	Temperature, °F
T_c	Cold Face Temperature, °F
T_h	Hot face Temperature, °F
T_m	Mean Temperature, °F
ΔT	Temperature difference between Hot and Cold Faces, °F
δ	Coefficient of variation.

INTRODUCTION

The temperature differentials and heat flow restrictions encountered for the X-20 Dyna-Soar vehicle required the development of reliable thermal conductance data. The requirements for insulation systems operating above 2000°F presented simultaneously the problems of the evaluation of the candidate materials at atmospheric and reduced pressures and the development of test apparatus which would yield accurate data.

A micro-quartz fiber felt insulation was selected for X-20 usage. This report provides the results of tests to evaluate the thermal conductivity of Q-felt, which is the trade name for micro-quartz fibers manufactured by the Johns-Manville Corporation. Prior to thermal exposure, Q-felt is soft, resilient and flexible and can be draped over contours and curved shapes. However, at temperatures above 1800°F, the quartz fibers change from an amorphous to a crystalline state which results in stiffening and shrinking of the fibers.

The term "thermal conductivity" as used in this report refers actually to "mean apparent thermal conductivity" since heat transferred through porous insulation materials is the result of all three basic mechanisms of heat flow; namely, gas and solid conduction, gas convection, and thermal radiation.

Heat flow through a porous material is not only a function of material density and temperature but also of pressure. This pressure phenomenon causes the thermal conductivity to decrease nonlinearly with decreasing pressure. Therefore, the thermal conductivity of Q-felt was evaluated for various densities under varying conditions of temperature and pressure.

The temperature and pressure ranges over which thermal conductivity measurements were required exceeded the capabilities of the conventional Guarded Hot Plate and Infinite Cylinder test apparatus. Consequently, the majority of the data was obtained using a Heat Flow Transducer apparatus. This apparatus uses the calibrated output of a thermopile element to sense the heat flow.

Thermal conductivity measurements on Q-felt were accomplished up to maximum hot face temperatures of approximately 2750°F and at pressures from atmospheric down to 0.10 mm of mercury. Several densities each of as-produced and thermally stabilized material were evaluated.

TEST PLAN

The tests reported in this document were conducted to provide mean apparent thermal conductivity data for both as-produced and thermally stabilized Q-felt in several densities over a range of test temperatures and pressures. These data were collected from tests conducted over a period of three years.

Atmospheric pressure tests for the as-produced material were conducted on 13 samples ranging from 3.55 to 7.5 lb/ft^3 density. Reduced pressure tests were conducted on 4 of these samples. One sample each was tested in an Infinite Cylinder Apparatus and a Guarded Hot Plate apparatus for comparison with the remainder of the testing accomplished using the Heat Flow Transducer apparatus. A total of 166 readings were accomplished on the as-produced material at hot face temperatures to 2000°F and at atmospheric and reduced pressures to 0.1 mm/Hg as shown in Table 1.

For the thermally stabilized material, 6 samples ranging in density from 4.95 to 10.8 lb/ft^3 were tested at atmospheric pressure. Reduced pressure tests were conducted on 3 of these samples. One sample was tested in the Infinite Cylinder apparatus and the remainder were tested using the Heat Flow Transducer test apparatus. A total of 80 readings were accomplished on the thermally stabilized material at hot face temperatures to 2750°F and at atmospheric and reduced pressures to one mm/Hg as shown in Table 2.

TABLE 1

TEST PLAN FOR UNSTABILIZED Q-FELT

[illegible] DENSITY, LB FT³		[illegible].45	[illegible]	4.6										[illegible]	[illegible].7	[illegible].75	[illegible].75	[illegible].7[illegible]	[illegible].06	[illegible]
Test Pressure, mm/Hg																				
Test Equipment	45° Face Temp., °F	760	760	760	400	90	20	10	5	1	0.5	[illegible]	0.1	760	760	760	760	760	760	760
Guarded Hot Plate	600														1					
	900														1					
	1000														1					
Infinite Cylinder	450																			1
	600																			1
	1050																			1
	1475																			1
	17[illegible]0																			1
Heat Flow Transducer	300																			
	400	1	1											2		2	1	1	2	
	500			1	1	1	1	1	1	1	1	1	1							
	800	1	1											1		1	1	1	1	
	1000			1	1		1		1	1	1	1	1							
	1100																			
	1200	1	1											1		1	1	1	1	
	1500	1	1	1	2		1		1	1	1	1	1	1		1	1	1	1	
	1600																			
	1800	1	1											1		1	1	1	1	
	2000			1	1		1		1	1	1	1	1							

[illegible] DENSITY, LB FT³		7.1								7.4									7.9			
Test Equipment	45° Face Temp., °F	760	400	20	5	1	0.5	[illegible]	0.1	760	90	400	20	5	1	0.5	[illegible]	0.1	760	90	5	1
Guarded Hot Plate	600																					
	900																					
	1000																					
Infinite Cylinder	450																					
	600																					
	1050																					
	1475																					
	17[illegible]0																					
Heat Flow Transducer	300																					
	400																		1	1	1	1
	500	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				
	800																					
	1000	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1			
	1100																					
	1200																		1	1	1	1
	1500	1	1	1	1	1	1	1	1	2	1	1	2	1	1	1	1	1				
	1600																					
	1800																		1			1
	2000	1	1	1	1	1	1	1	1	1	1	2	2	1	1	1	1	1		1	1	1

TABLE 2

TEST PLAN FOR THERMALLY STABILIZED Q-FELT

SPECIMEN DENSITY, LB/FT^3		4.95	5.84					6.21					6.34	8.0				10.8
Test Pressure, mm/Hg																		
Test Equipment	Approx. Hot Face Temp., °F	760	760	100	30	10	3	760	100	30	10	3	760	760	30	5	1	760
Infinite Cylinder	450																	1
	700																	1
	1000																	1
	1500																	1
	1800																	1
	2200																	1
Heat Flow Transducer	400		1											1	1	1	1	
	500	1																
	700												2					
	900													1			1	
	1000	1						2	1	1	1	1						
	1300													1	1	1	1	
	1400												1					
	1500	1						2	1	1	1	1						
	1750													1			1	
	1900												1					
	2000	1						2	1	1	1	1						
	2150													1	1	1	1	
	2250	1	1	1	1	1	1	1	1	1	1	1						
	2400							1					1					
	2500	1	1	1	1	1	1	1	1	1	1	1		1				
	2600										1						1	
	2750	1						1								1	1	

MATERIAL

The material tested in this program is intended for thermal insulation of structures exposed to extremely high temperature environments. This insulation is a felt composed of interlaced micro-quartz fibers. The fibers are .75 to 1.5 microns average diameter and are composed of a minimum of 98.5 weight percent silicon dioxide. This material is commonly known as Q-felt which is a trade name for micro-quartz fibers manufactured by the Johns-Manville Corporation which supplied all of the material used in this program.

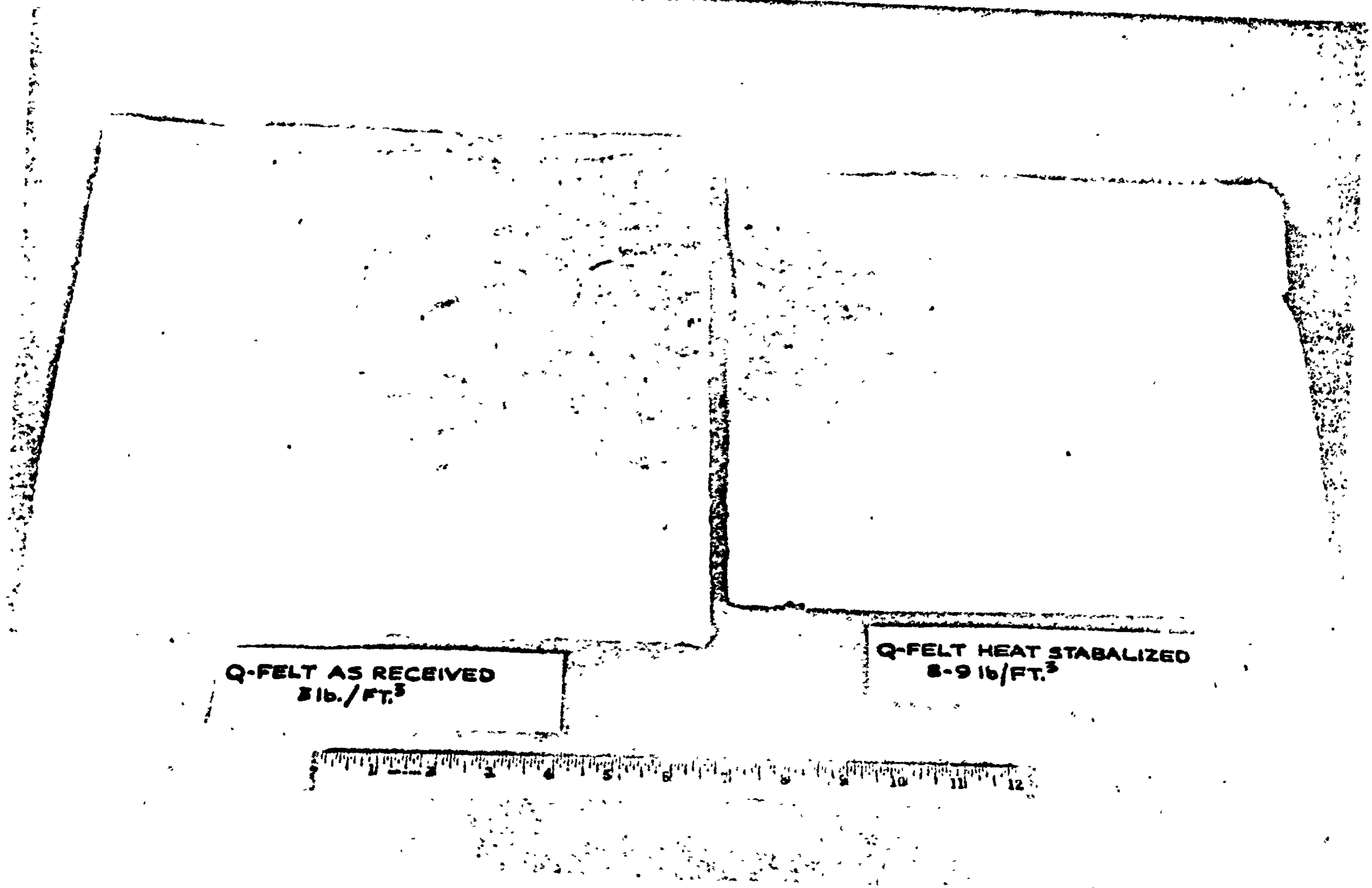
The Q-felt tested in this program was of two types. Type I is the normal "as-produced" condition and is soft and flexible and can be draped over contours and curved shapes. Its nominal density is 3.0 to 3.5 pounds per cubic foot in the as-received condition. Testing was accomplished on Type I material of nominal densities from 3.5 to 7.5 lb/ft^3. The as-received material was mechanically compressed to the required density for testing.

Exposure of Type I material to temperatures in excess of 1800°F results in a significant change in its physical state. At these high temperatures, the quartz fibers devitrify or change from an amorphous to a crystalline state. The result of this is a shrinking and stiffening of the fibers which converts it to a rigid state. The insulation can be thermally exposed to obtain a heat stabilized condition where phase changes and densification of the fibers are nearly complete and dimensional stability for higher temperature applications is attained. A thermal exposure to 2200°F for 3 hours results in a condition which exhibits less than 1% additional shrinkage when exposed to temperatures of 2750°F for 30 minutes. Material which has been thermally stabilized is designated as Type II. Figure 1 shows a sample of Q-felt in both the as-received and heat stabilized conditions.

Tests were conducted on several densities of the Type II material. This material was mechanically compressed prior to thermal stabilization to yield densities ranging from 4.9 to 10.8 lb/ft^3.

A Boeing Material Specification was prepared to provide procurement control of Q-felt. This specification was prepared under close coordination with the material supplier to provide a more uniform product and prevent high temperature reactions due to impurities in the product. A copy of this specification is provided in Appendix C.

Figure 1
Q-FELT SAMPLES IN THE AS-RECEIVED AND THERMALLY STABILIZED CONDITIONS



TEST EQUIPMENT AND PROCEDURES

Three types of conductometer apparatus were used for the measurements of thermal conductivity presented in this report. They are as follows:

1. Guarded Hot Plate Apparatus

2. Infinite Cylinder Apparatus

3. Heat Flow Transducer Apparatus

A summarized comparison of these pieces of equipment is presented in Table 3. The majority of the test data was generated using the Heat Flow Transducer due to the temperature and pressure requirements dictated by the anticipated X-20 environment. The Guarded Hot Plate and Infinite Cylinder apparatus were used primarily as back up for the calibration of the Heat Flow Transducer.

The Guarded Hot Plate has been fully described in ASTM publications and has been the standard testing method for conductivity measurements for more than a decade. The unit used in this program was constructed to the requirements of ASTM C-177-45.[1] Figure 2 shows a partly disassembled view of this apparatus.

The Infinite Cylinder type of apparatus has been used extensively by numerous investigators because the equipment offers few design problems for theoretically accurate thermal conductivity determination. This type of apparatus has been adequately described in published literature.[2] Comprehensive discussions on the Guarded Hot Plate and Infinite Cylinder may be found in most text books dealing with heat transfer. Figure 3 shows a partly disassembled view of the Infinite Cylinder apparatus.

The Heat Flow Transducer apparatus used throughout this test program was developed from a lower temperature capability laboratory unit initially built in 1956. Figure 4 shows a schematic of the present apparatus. The heat flow sensing element is a thermopile transducer, a flat core around which is wound a number of differential thermocouples connected in series. Figure 5 shows the components of the sensing unit. In operation, the thermopile produces an electromotive force (EMF) proportional to the temperature gradient between the hot and cold junctions. For a given heat flow rate, the output of the transducer depends upon the number of differential couples making up the sensing unit and the thermal conductivity of the core material. After proper calibration, the EMF output may be translated into heat units of $BTU/sec\text{-}in^2$.

The heat source is composed of two independent heaters, a five inch square main unit and a one and one-half inch wide guard ring. This configuration makes available an effectively uniformly heated area approximately 6 inches square. Two heat sources were used. One uses "Kanthal-A" resistive wire elements in both the main and guard heaters and is capable of producing temperatures to 2200°F. For temperatures up to 2800°F, a silicon carbide globar main heater with a platinum-rhodium wire wound guard ring configuration was used.

Thermocouples were placed on both the hot face and cold face of the insulation specimen to allow measurement of the temperature drop across the specimen, and computation of the mean temperature. A lagging insulatio was placed between the

specimen cold face and the thermopile transducer to maintain a reasonable temperature gradient (200°F to 500°F) through the test sample. The thermopile transducer was approximately 2 inches square and was bonded directly to the water cooled copper heat sink.

Figure 6 shows the 2800°F conductometer partly disassembled. The temperature head has been placed at the rear. The four darker spots near the corners of the 9 x 9 inch square sample are silicon carbide spacers used to support the temperature head and maintain the required specimen thickness.

The steady state heat flow condition required for all conductivity tests was considered established when all pertinent measurements had stabilized for a period of one hour. From measurements of the EMF generated by heat flowing through the transducer, the hot and cold face temperatures and the thickness of the specimen, thermal conductivity is found by the equation below for unidirectional heat flow in the steady state.

$$K = \frac{Qt}{\Delta T}$$

where:

K = The apparent mean thermal conductivity in 10^{-6} BTU-in/sec.-in^2-°F

ΔT = The temperature drop across the sample in °F

t = The sample thickness in inches

Q = The heat flow through the transducer in 10^{-6} BTU/sec-in^2 (Q is determined by multiplying the EMF output of the transducer in millivolts by the transducer calibration factor in BTU/sec-in^2-millivolt)

For the measurements of thermal conductivity at reduced pressures, the Heat Flow Transducer apparatus was mounted in an 18" glass bell jar. The bell jar base plate contained sealed connectors to accommodate all power leads, instrument leads, and coolant pass throughs. Figure 7 shows the vacuum test set up.

The Q-felt samples were mounted in the test apparatus and the first reading was taken at the lowest temperature. Where only atmospheric pressure readings were taken, the specimen temperature was raised in increments and readings taken after the required stabilization period until the highest temperature was reached. When reduced pressure tests were performed, the initial temperature was held and the pressure reduced the required increments until the lowest pressure was recorded. The temperature was then increased to the next increment while holding this low pressure and this series of readings were taken by increasing the pressure through the required increments. This resulted in readings taken alternately at decreasing and then increasing pressure increments for the various temperatures.

TABLE 3

THERMAL CONDUCTIVITY APPARATUS COMPARISON

Apparatus	Method of Heat-Flow Measurement	Maximum Hot-Face Temperature	Test Specimen Size	Remarks
Guarded Hot Plate ASTM C-177-45	Electrical Energy (watts)	1200°F	8 in. dia. Max. 1 in. thick	Advantages: No calibration Established design Disadvantages: Low max. temp. Requires large vacuum chamber Slow equilibrium attainment (2-6 hours)
Infinite Cylinder	Electrical Energy (watts)	2200°F	Cylinder 2 in. I.D. 12 in. long	Advantages: Established design No calibration Adaptable for vaccum operation Disadvantages: Difficult sample preparation Distortion of test specimen Slow equilibrium attainment (2-6 hours)
Heat Flow Transducer	Calibrated Meter (BTU/sec-in^2-mv)	2800°F	8 in. square max. 1 in. thick	Advantages: Easy sample preparation Adaptable for vacuum operation Faster equilibrium attainment (3 hours max.) Disadvantages: Calibration necessary

Figure 2
GUARDED HOT PLATE TEST APPARATUS

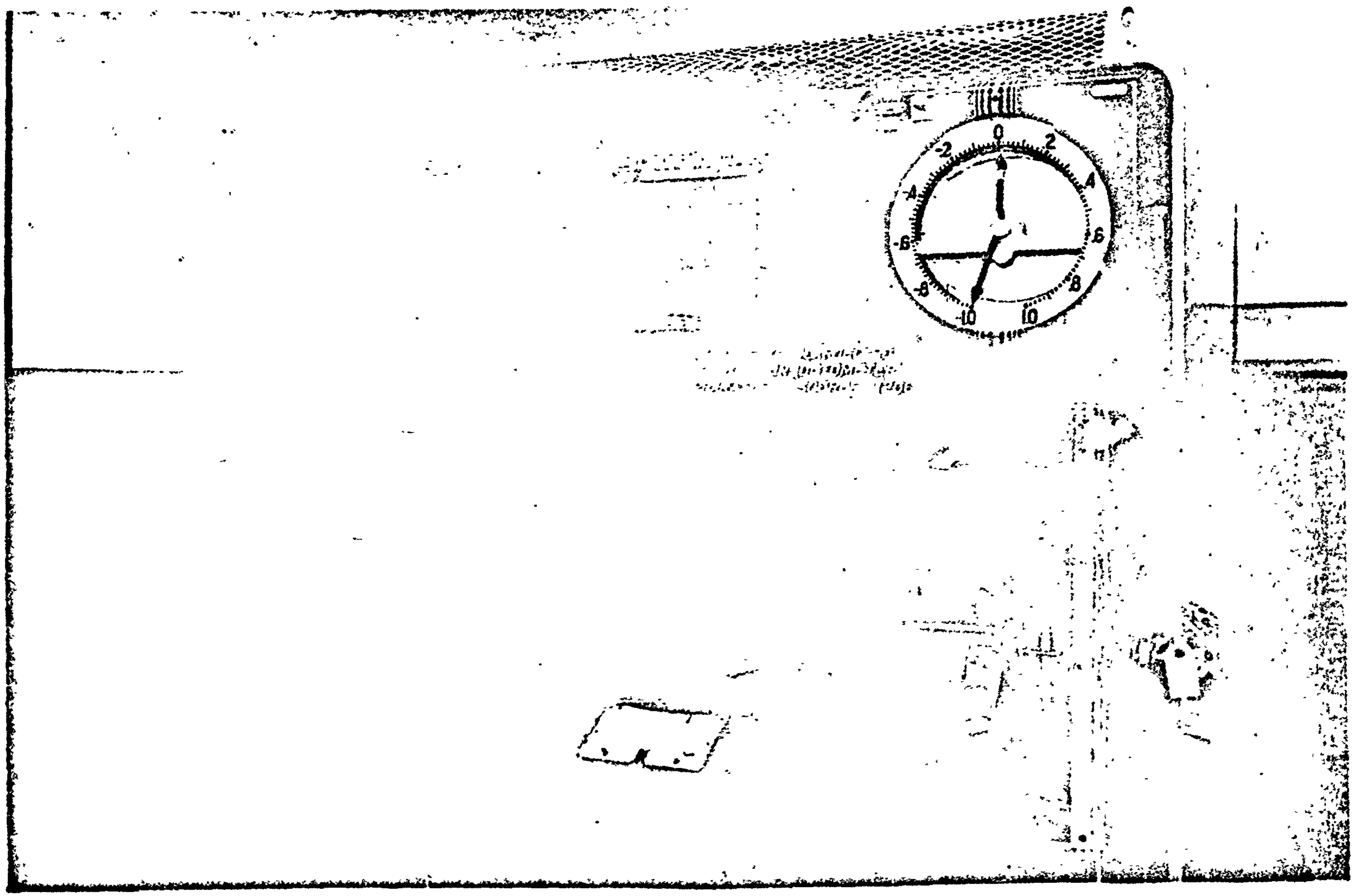


Figure 3
INFINITE CYLINDER TEST APPARATUS

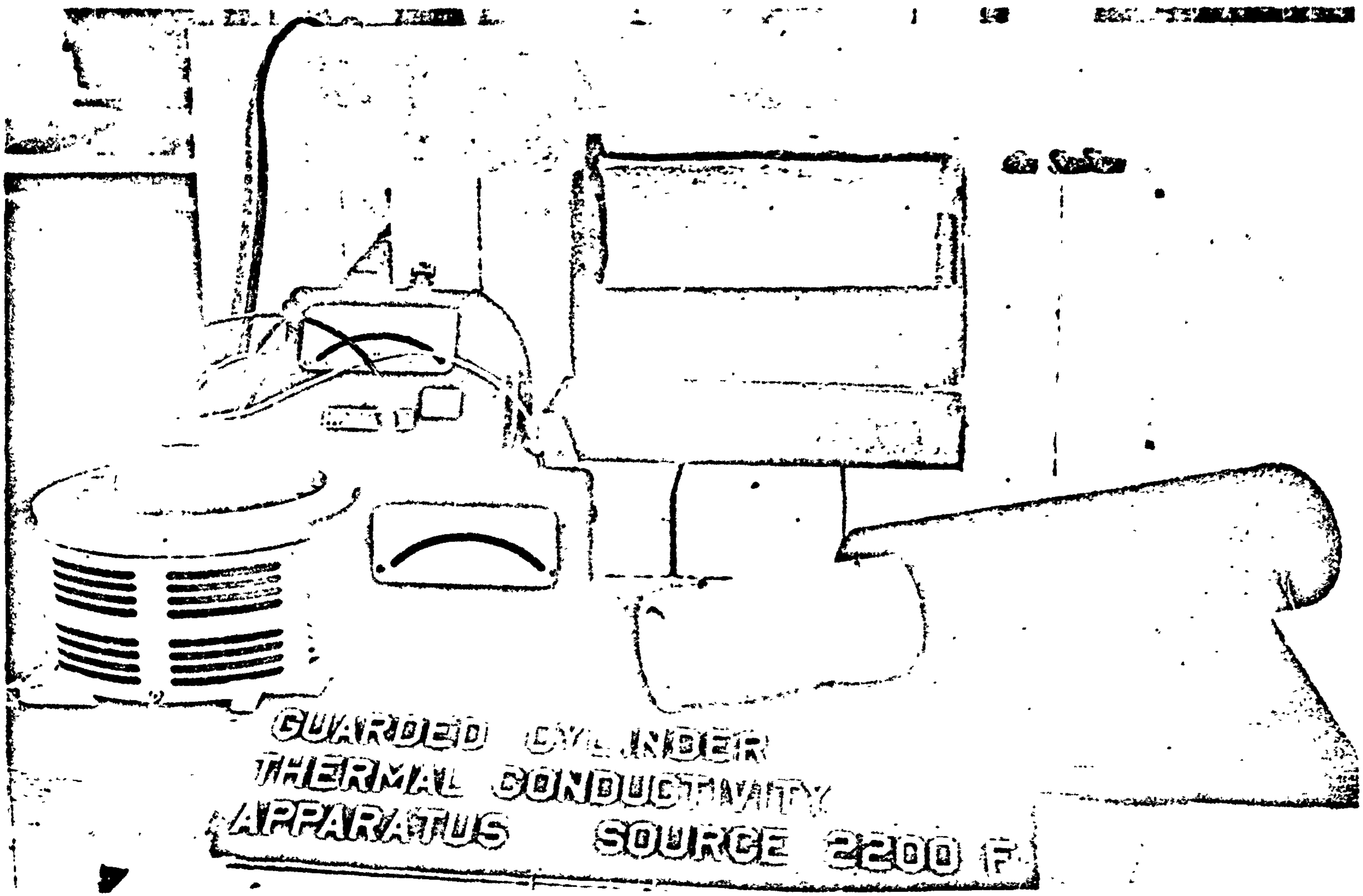


FIGURE 4

SCHEMATIC OF HEAT FLOW TRANSDUCER APPARATUS

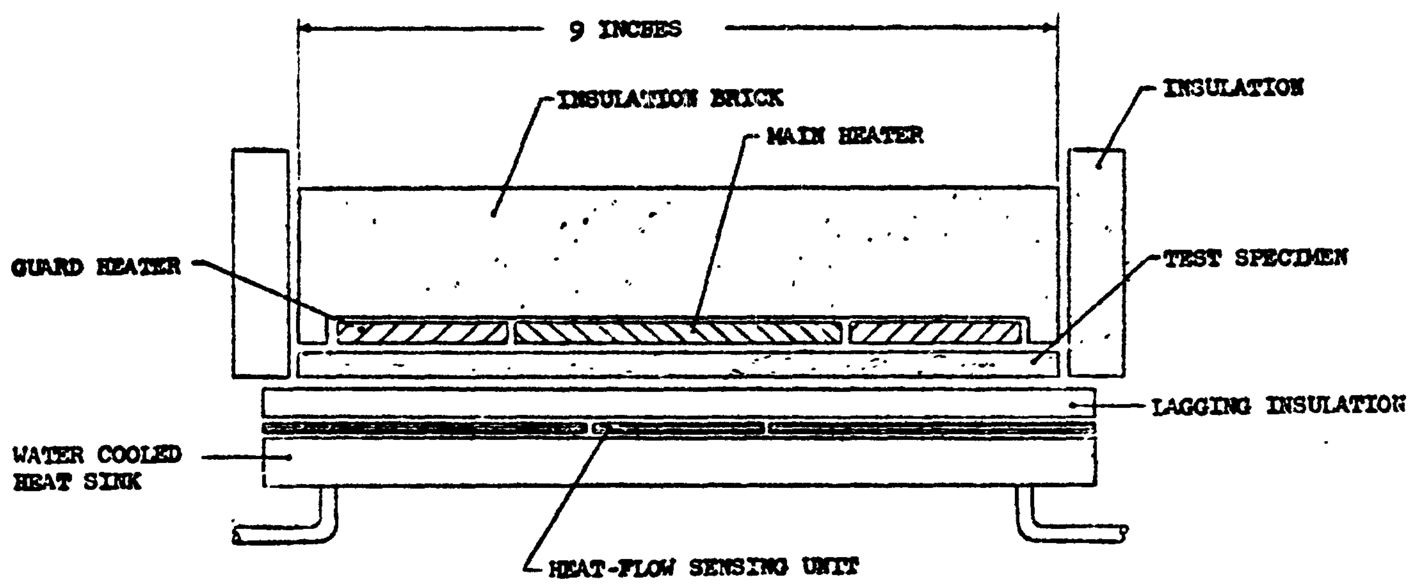


FIGURE 5

HEAT FLOW TRANSDUCER SENSING UNIT

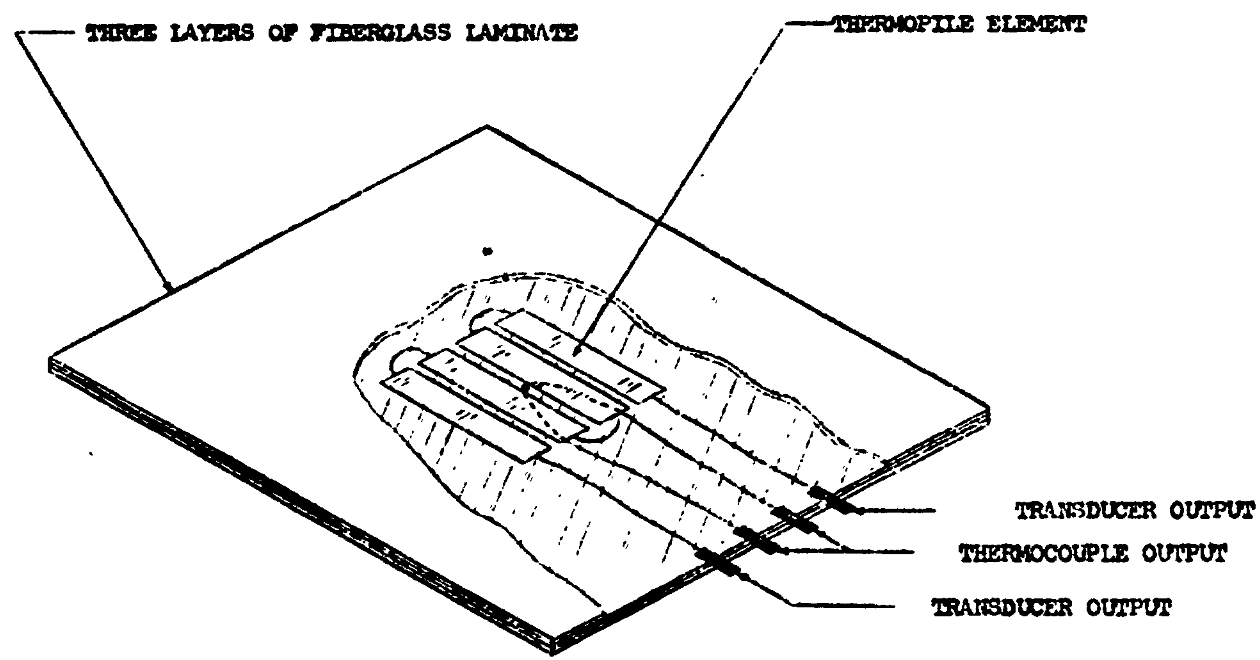
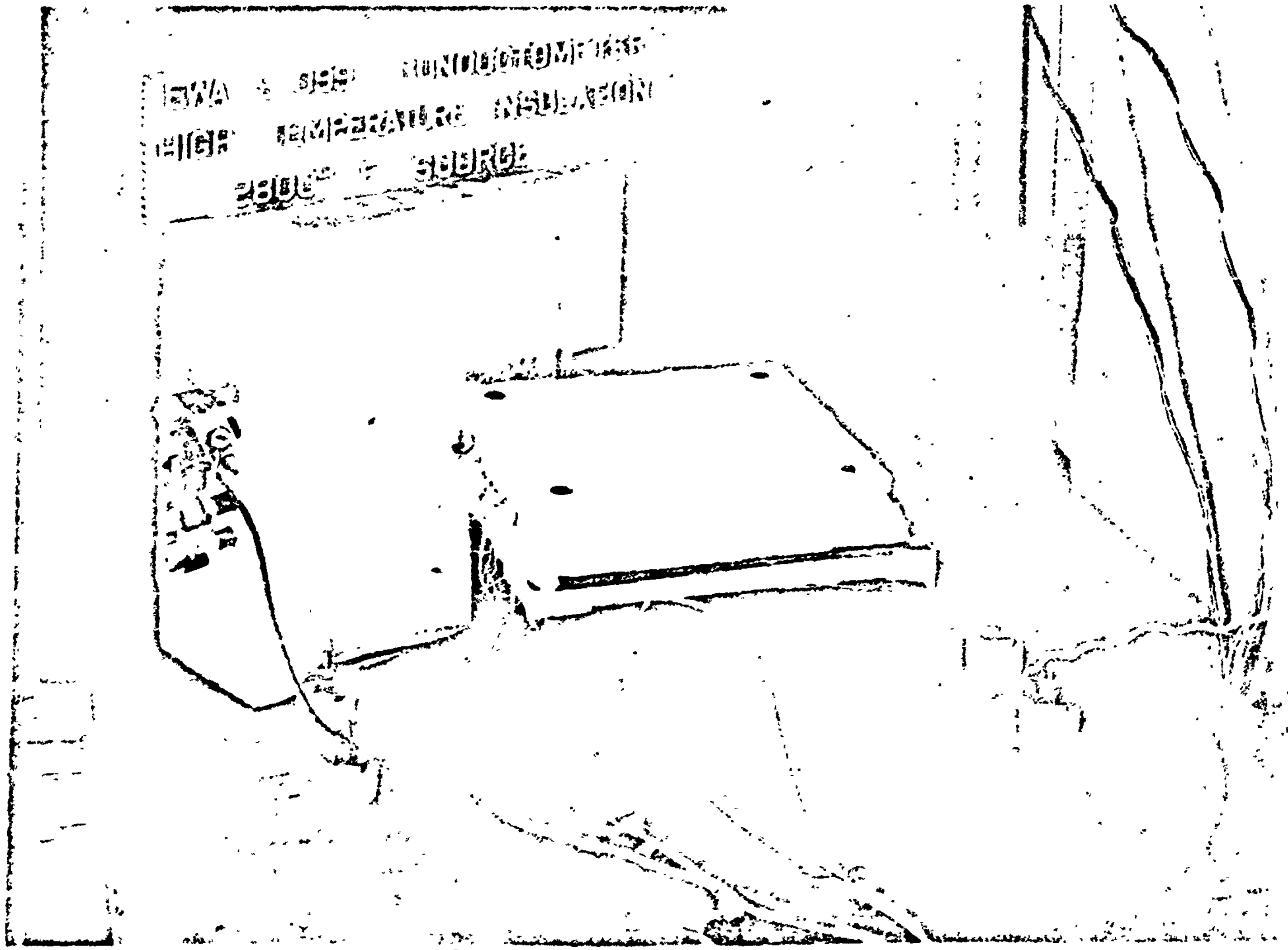


Figure 6
HEAT FLOW TRANSDUCER APPARATUS



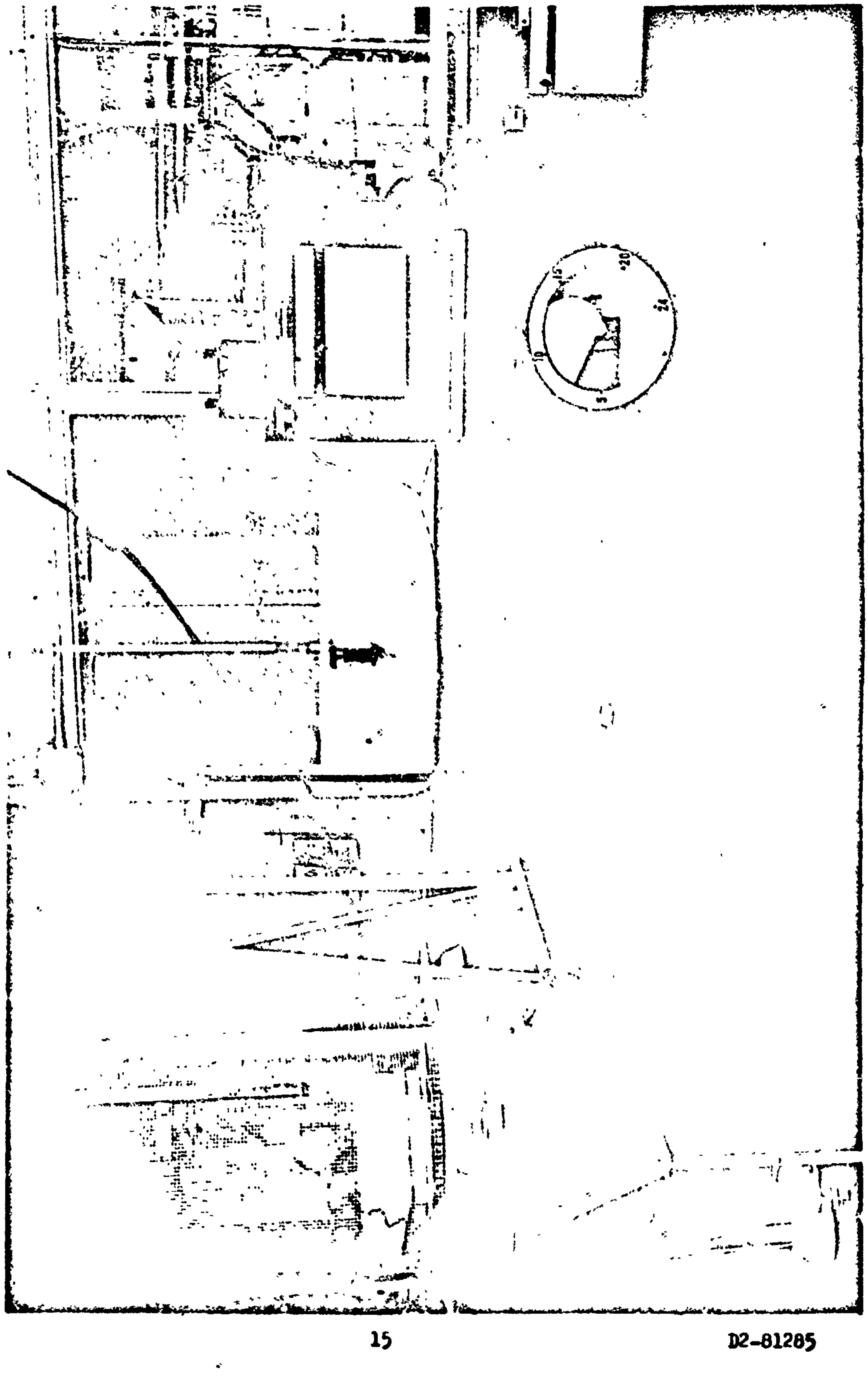


Figure 7
REDUCED PRESSURE TEST SET-UP FOR HEAT FLOW TRANSDUCER APPARATUS

TEST DATA AND ANALYSIS

The test data generated in this program was combined with other previously published data and an analysis made to determine suitable design allowable thermal conductivity values.

Due to the nonlinear influence of test temperature, pressure and material density on the mean apparent thermal conductivity, a comparative method was used to evaluate the data. The actual test data generated in this program are presented in Appendix B for those wishing to review the raw data.

The effect of test temperature and pressure was determined for each specimen. Nominal thermal conductivity curves were developed for each specimen by plotting the test data versus temperature and fairing curves through the data points. For those specimens for which reduced pressure data was obtained, an additional plot of thermal conductivity versus pressure was prepared and nominal curves for several selected temperatures were drawn. These curves are included in Appendix A. The referenced test data included in the analysis was treated in the same manner and plots of these data are also included in this appendix.

It was necessary to determine these nominal temperature and pressure relationships for each individual specimen since exact duplication of test conditions were not obtained between specimens. Determination of these nominal relationships then allowed interpolation to several specific temperatures and pressures in order to obtain a comparison between specimens.

The individual specimen results were then compared by plotting the interpolated thermal conductivity value for the selected temperature and pressure as a function of specimen density as shown in Figures 8 through 13. Mean temperatures of 400, 900, 1400, and 1800°F were selected for comparing the unstabilized material. In addition, 2000, 2250, and 2500°F temperatures were included for thermally stabilized material. The pressures selected for comparison were 760, 100, 20, 5, 1, and 0.1 mm/Hg.

Best estimate average property curves were then drawn through this cross plotted data to define the most likely thermal conductivity versus density relationship for the selected temperatures and pressures. The most data was available for atmospheric pressure (760 mm/Hg) as shown in Figure 8. Consequently this data was used to develop the basic trends at the various temperatures.

Data in References (3), (4), and (6) in general agrees quite well with the data generated in this program. No significant difference is evident between unstabilized and thermally stabilized material at a given density. Therefore, all data was grouped together to define the most likely average property curves.

For the higher temperatures and at some of the reduced pressures, the small amount of data available required some interpretation of the data in order to draw the curves. In these cases, the average curve placement took account of the relationship of the particular specimens to the average curves at lower temperatures and pressures where sufficient data existed. For example, the average curve for 2500°F in Figure 8 was placed about 15% above the data point at 8.0 lb/ft^3 since the data points for this 8.0 lb/ft^3 specimen averaged about 15% below the average lines at 1400, 1800, and 2000°F.

Design allowable thermal conductivity values are presented as average properties with a stated range since the intended application will govern whether maximum or minimum values are conservative. The average property curves developed above were used to prepare design allowable curves for several selected densities. These are presented in Figure 16 through 21. The range of material variation is provided on these curves to allow the user to adjust the values to suit the application.

Sufficient duplication of test conditions were not obtained to allow a rigorous analysis of variance at the various conditions of density, pressure, and temperature. An estimate of variation was obtained, however, by grouping some of the data.

The first group consisted of the eleven sets of data for unstabilized Q-felt of 3.9 ± 0.4 lb/ft^3 as summarized in Figure 14. The variation in thermal conductivity about the mean for five temperatures was examined. The density and each temperature were treated as controlled independent variables which assigned all of the variation effect to the measured thermal conductivity values. A statistical analysis was then performed on this set of data to determine the coefficient of variation which was calculated as follows:

$$\delta = \sqrt{\frac{\sum \left|\frac{K - \bar{K}}{\bar{K}}\right|^2}{n - 1}}$$

where: δ = the coefficient of variation

K = the individual measured value of thermal conductivity

$\bar{K}$ = the average of the measured values

n = the number of individual values.

A summary of the values determined from this group of data is provided below. The coefficient of variation indicates that the variation at the several temperatures is not significantly different. The average coefficient of variation for all five temperatures is 7.4%.

TABLE 4

Statistical Summary of 3.9 ± .04 lb/ft^3 data

Temperature, °F	325 ± 25	710 ± 10	1080 ± 20	1370 ± 30	1640 ± 15
n	13	8	8	10	7
$\bar{K}$	.720	1.1525	1.6750	2.1880	2.7671
$\sum \left\|\frac{K - \bar{K}}{\bar{K}}\right\|^2 \times 10^4$	725.3	371.5	400.62	509.6	296.4
δ	7.78%	7.29%	7.56%	7.53%	7.04%

If the dispersion of the values of the dependent variable are of approximately equal percentage of average regardless of the value of the independent variable, an approximate method for estimating the variation about a fitted irregular curve may be used. As this was the case for the data above, this technique was applied to the interpolated data shown in Figure 8 which grouped all atmospheric pressure tests of all densities and both unstabilized and thermally stabilized material. This was used to get an estimate of the variation about the average property curves determined previously.

In this procedure, the coefficient of variation is calculated from the deviations of the individual value from the average curve value at the particular density. This procedure assigns all of the variation to the dependent variable K which is consistent with the technique used to present the variation range on the allowable curves. The summarized analysis of the data included in Figure 8 is shown below.

TABLE 5

Statistical Summary Atmospheric Pressure Data

Temp., °F	400	900	1400	1800	2000	2250	2500
n	21	24	23	13	11	6	4
$\sum \left(\frac{K-\bar{K}}{\bar{K}}\right)^2 \times 10^4$	1420.66	1823.27	1684.37	1237.91	935.40	788.64	245.30
δ	8.43%	8.91%	8.75%	10.15%	9.67%	12.55%	9.04%

The coefficient of variation for this set of data is compared to that for the first group in Figure 15. There is reasonable agreement at all temperatures. The slight increase indicated at the higher temperatures is not considered significant due to the smaller number of data points at these temperatures. This indicates that a single pooled coefficient of variation may be used to determine the best estimate limits applicable to the design allowable curves.

$$\hat{\delta}^2 = \frac{\delta_1^2 (n_1-1) + \delta_2^2 (n_2-1) + \dots \delta_m^2 (n_m-1)}{n_1 + n_2 + \dots n_m - m}$$

where: $\hat{\delta}$ = the pooled coefficient of variation for m groups of data

δ = the coefficient of variation for the individual data group, the subscripts indicating the particular group.

n = the number of individual values in the group of data, subscripts indicate the particular group.

m = the total number of data groups.

Substituting actual values into the above equation from Table 5, we get a pooled coefficient of variation of 9.25% for the 102 data points. The limit values are then determined (at a confidence level of 95%) by multiplying this coefficient

of variation by the appropriate statistical k factor. For a probability that 90% of the values will not exceed the limit (equivalent to MIL-HDBK-5 "B" values), k = 1.534. For 99% probability (equivalent to MIL-HDBK-5 "A" values), k = 2.695. The limits are as follows:

Reliability	Upper Limit	Lower Limit
$C_{.95} - P_{.90}$	$\bar{K}$ + 14%	$\bar{K}$ - 14%
$C_{.95} - P_{.99}$	$\bar{K}$ + 25%	$\bar{K}$ - 25%

These are the limits used on the allowable curves shown in Figure 16 through 21.

FIGURE 8

DENSITY EFFECT ON THERMAL CONDUCTIVITY OF Q-FELT AT ATMOSPHERIC PRESSURE

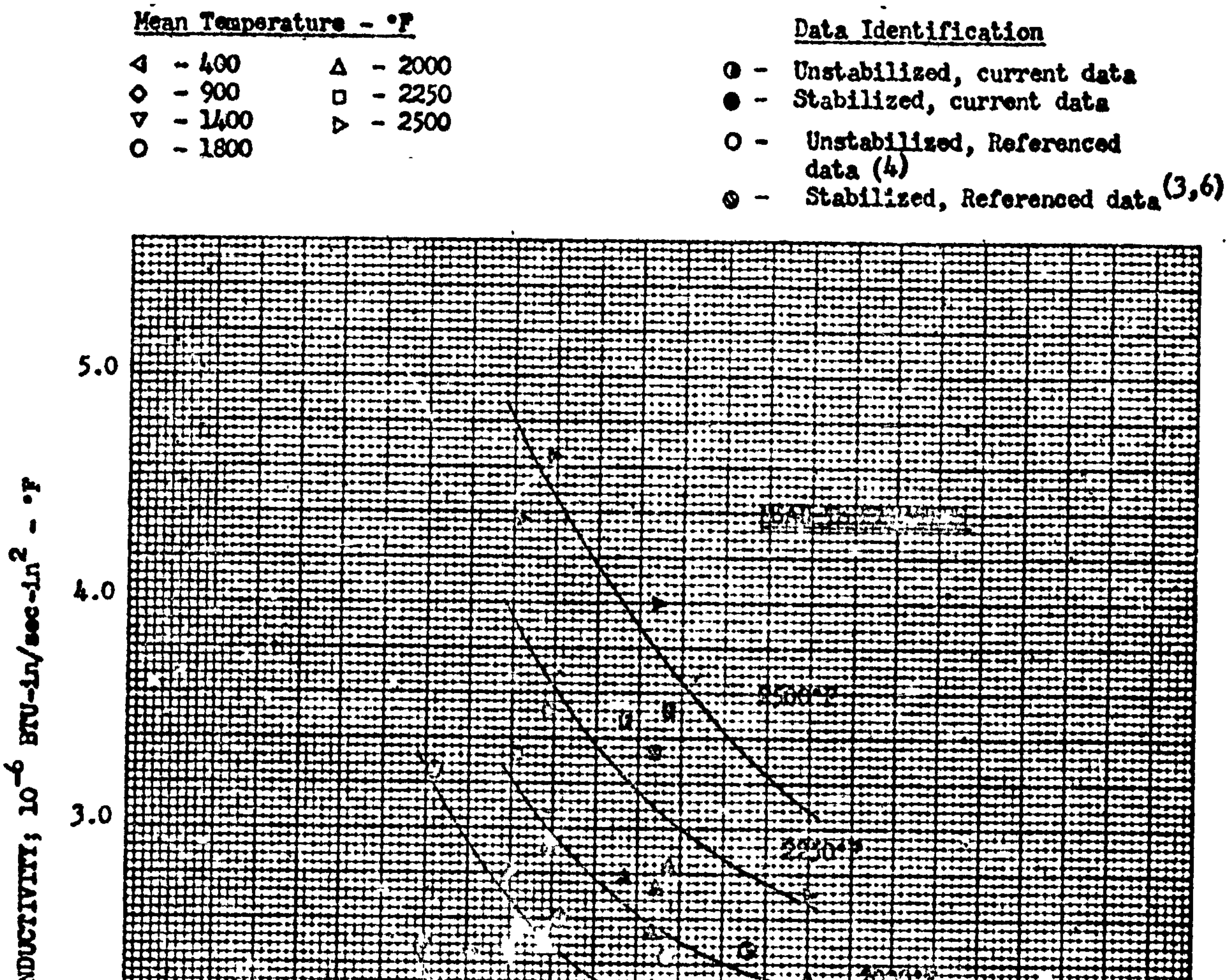


FIGURE 9

DENSITY EFFECT ON THERMAL CONDUCTIVITY OF Q-FELT AT 100 mm/Hg PRESSURE

Mean Temperature - °F

◁ - 400
◇ - 900
▽ - 1400
○ - 1800
△ - 2000
□ - 2250
▷ - 2500

Data Identification

◐ - Unstabilized, current data
● - Stabilized, current data
⊘ - Stabilized, Referenced data(6)

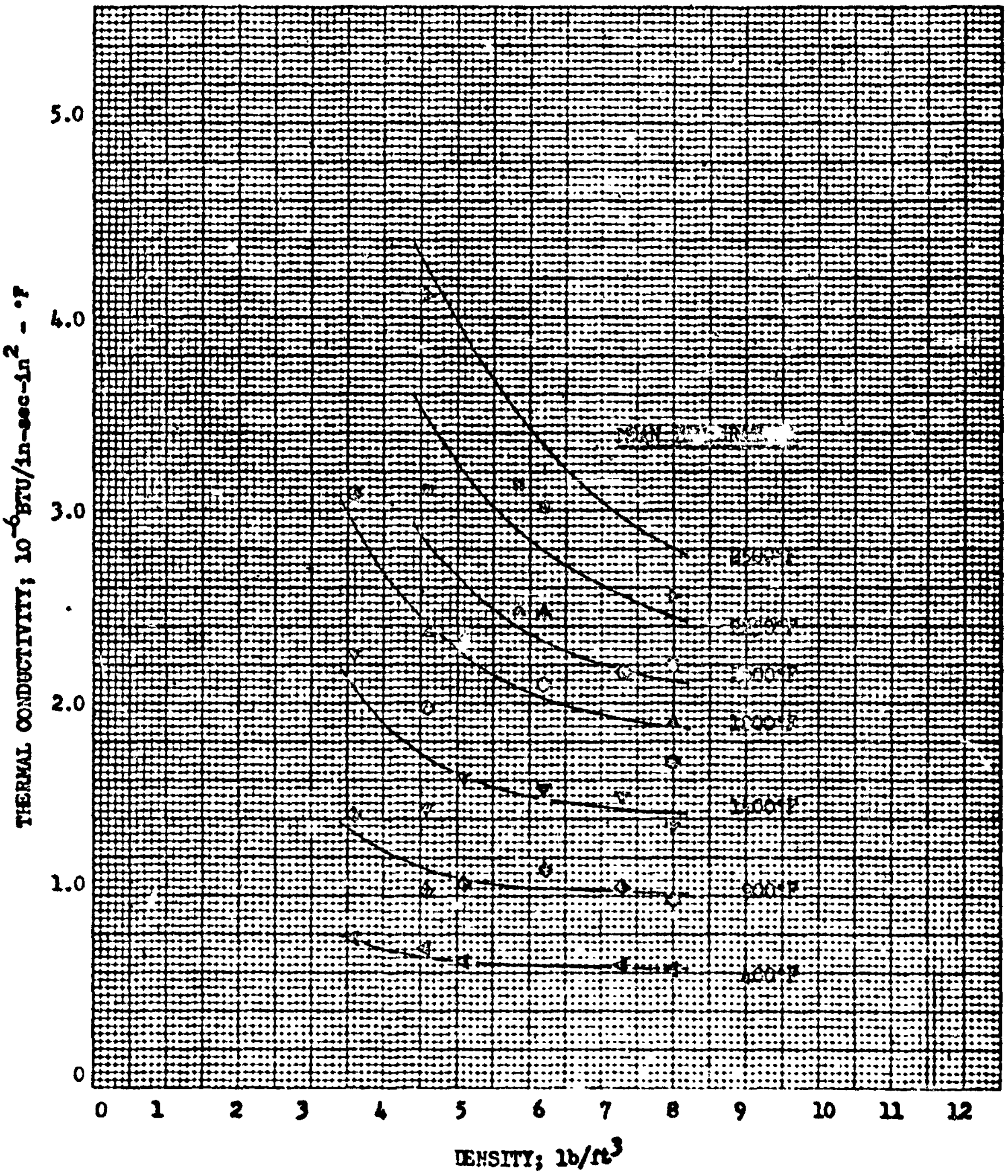


FIGURE 10

DENSITY EFFECT ON THERMAL CONDUCTIVITY OF Q-FELT AT 20 mm/Hg PRESSURE

Mean Temperature - °F

◁ - 400
◇ - 900
▽ - 1400
○ - 1800
△ - 2000
□ - 2250
▷ - 2500

Data Identification

◑ - Unstabilized, Current Data
● - Stabilized, Current Data
⊘ - Stabilized, Referenced Data(6)

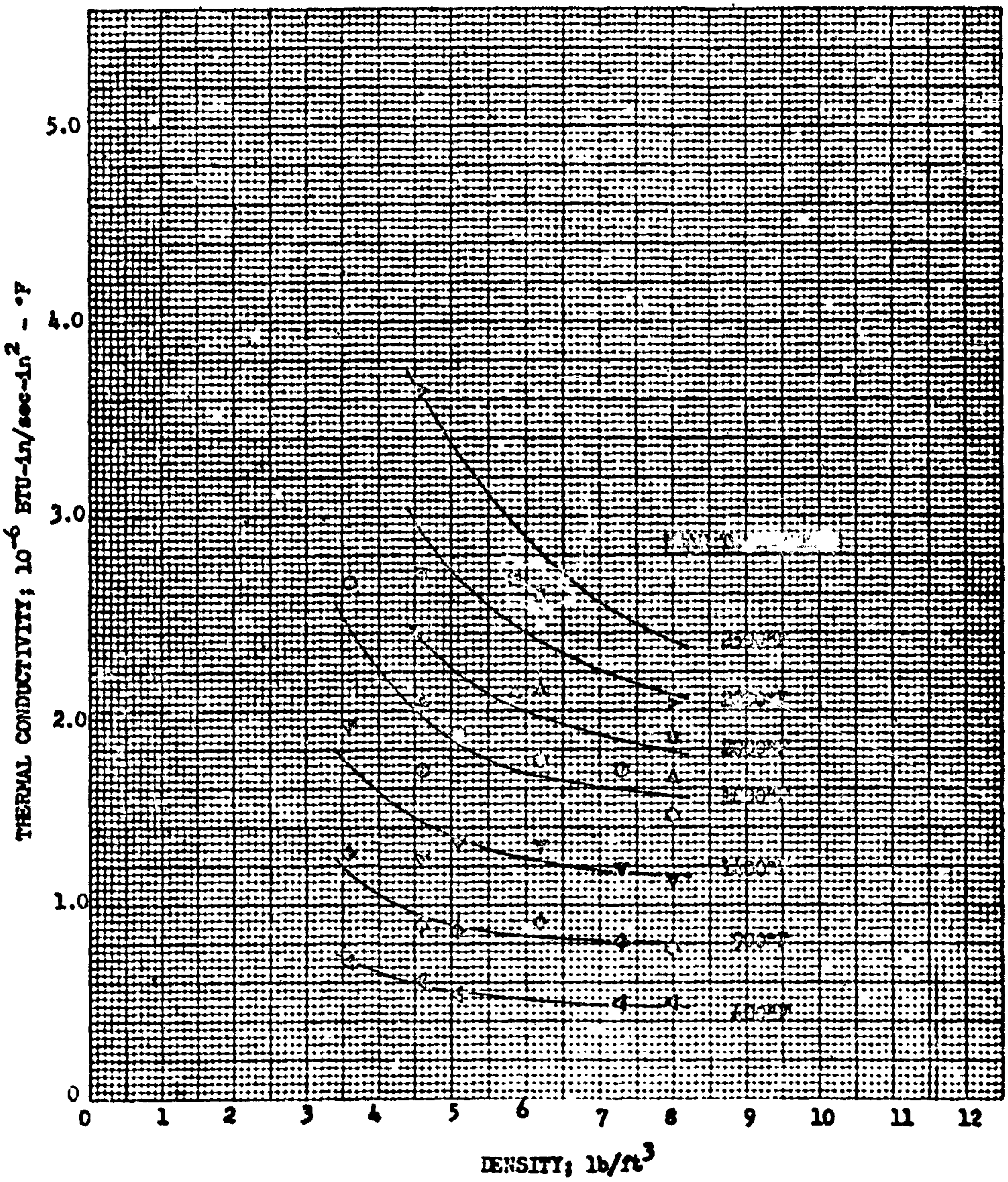


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FIGURE 11

DENSITY EFFECT ON THERMAL CONDUCTIVITY OF Q-FELT AT 5 mm/Hg PRESSURE

Mean Temperature - °F

◁ - 400
◇ - 900
▽ - 1400
○ - 1800
△ - 2000
□ - 2250
▷ - 2500

Data Identification

○ - Unstabilized, Current Data
● - Stabilized, Current Data
◉ - Stabilized, Referenced Data (6)

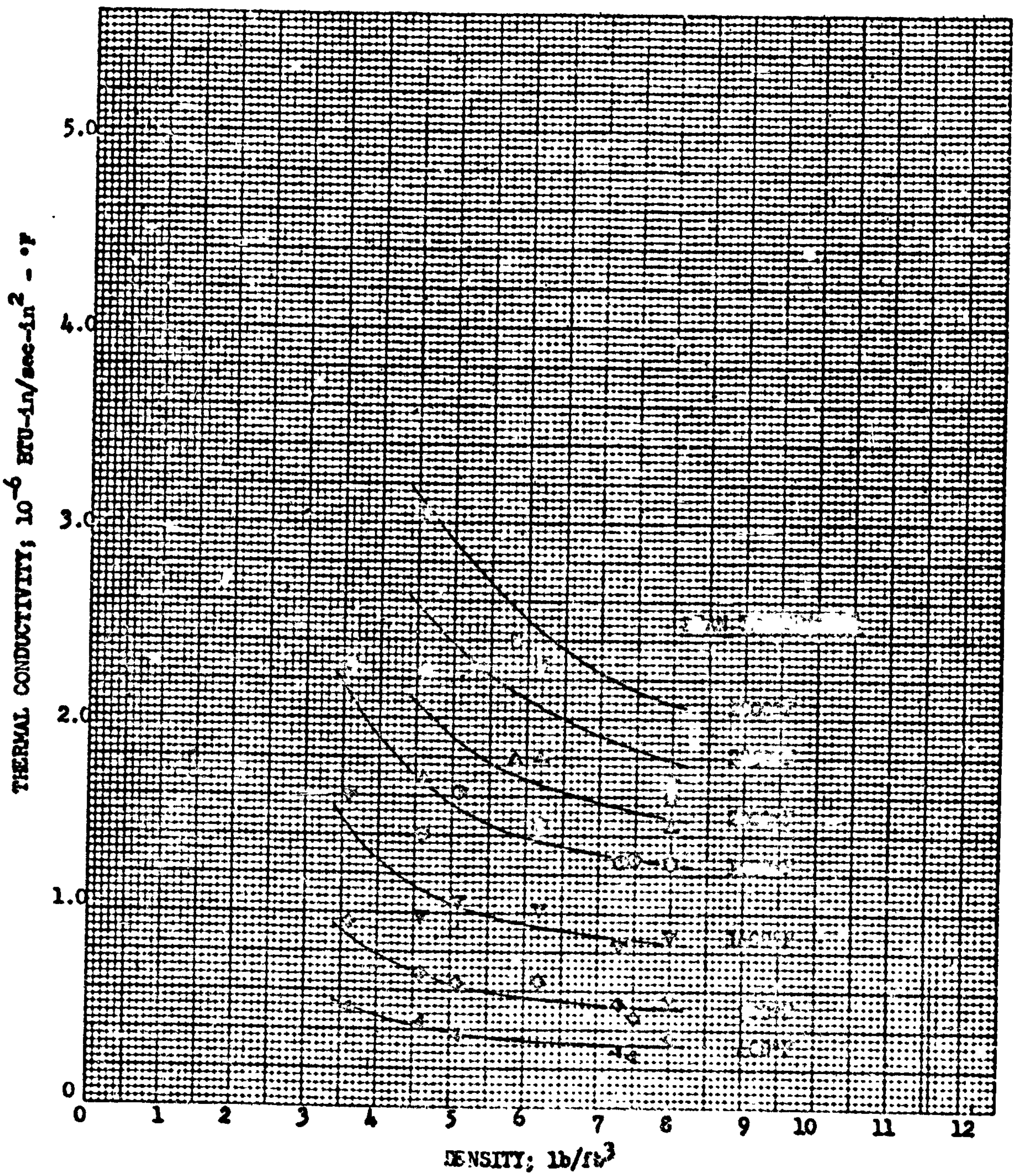

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FIGURE 12

DENSITY EFFECT ON THERMAL CONDUCTIVITY OF Q-FELT AT 1 mm/Hg PRESSURE

Mean Temperature - °F

◁ - 400
◇ - 900
▽ - 1400
○ - 1800
△ - 2000
□ - 2250
▷ - 2500

Data Identification

◐ - Unstabilized, Current Data
● - Stabilized, Current Data
⊘ - Stabilized, Referenced Data (6)

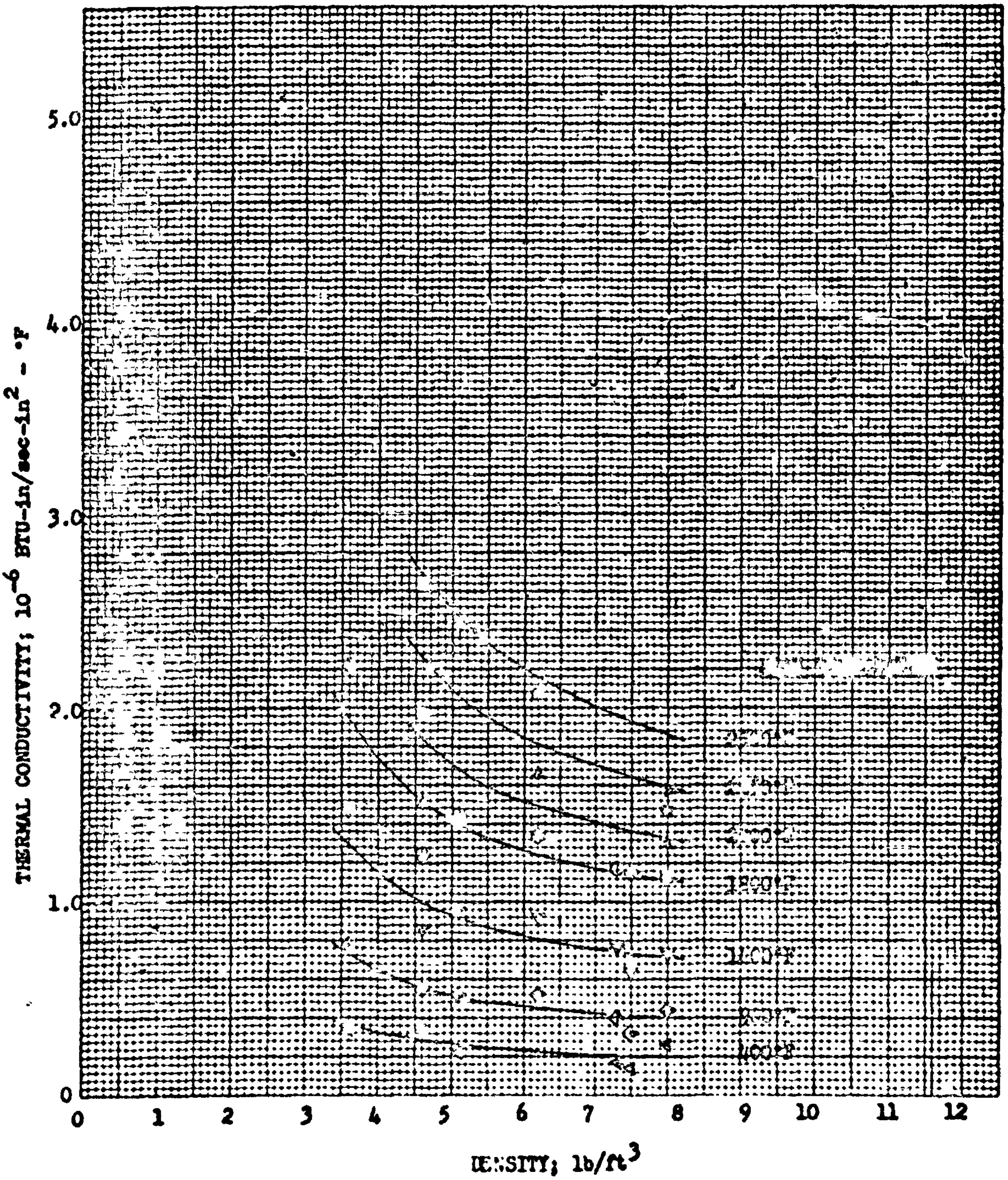
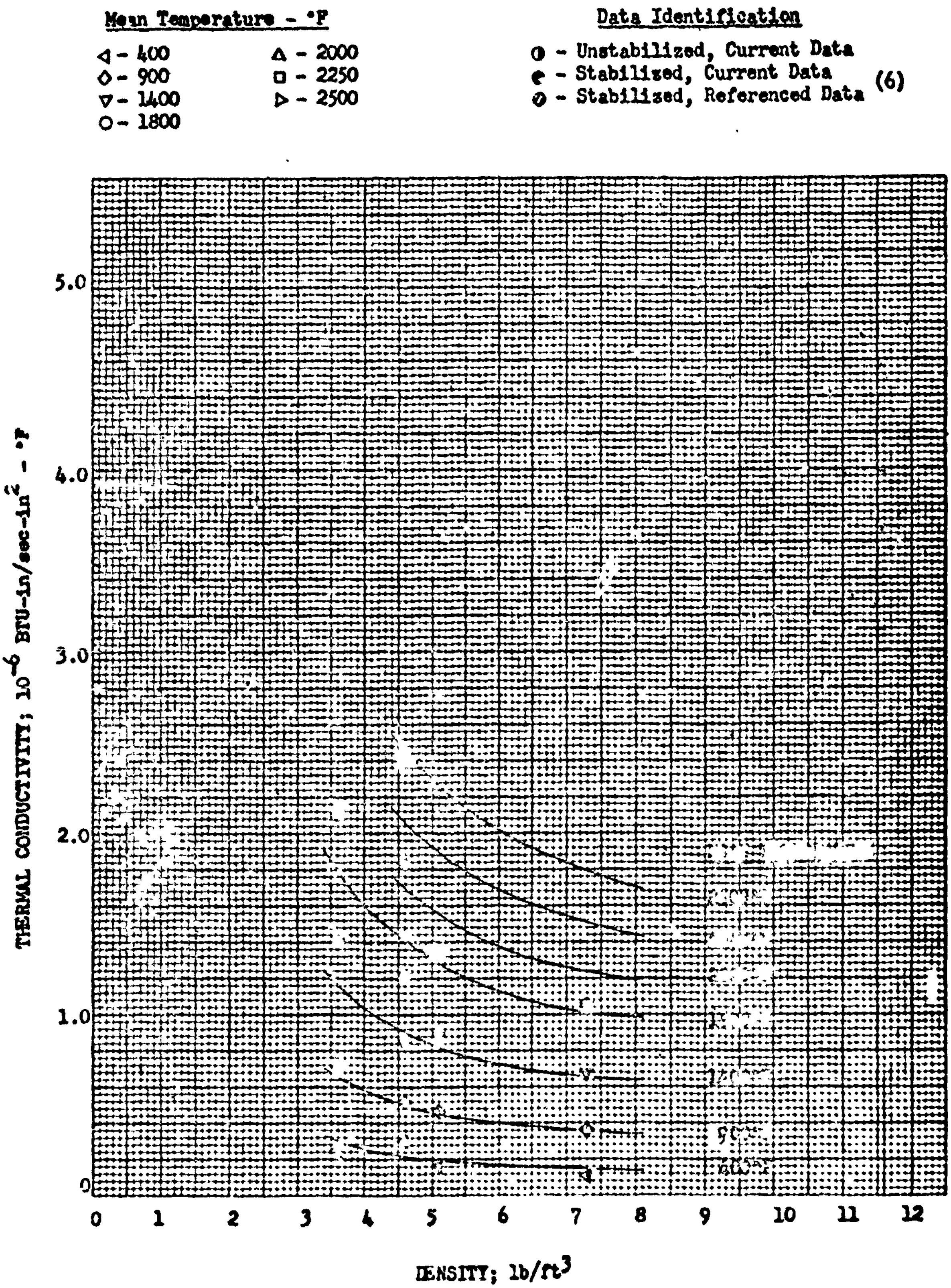


FIGURE 13

DENSITY EFFECT ON THERMAL CONDUCTIVITY OF Q-FELT AT 0.1 mm/Hg PRESSURE



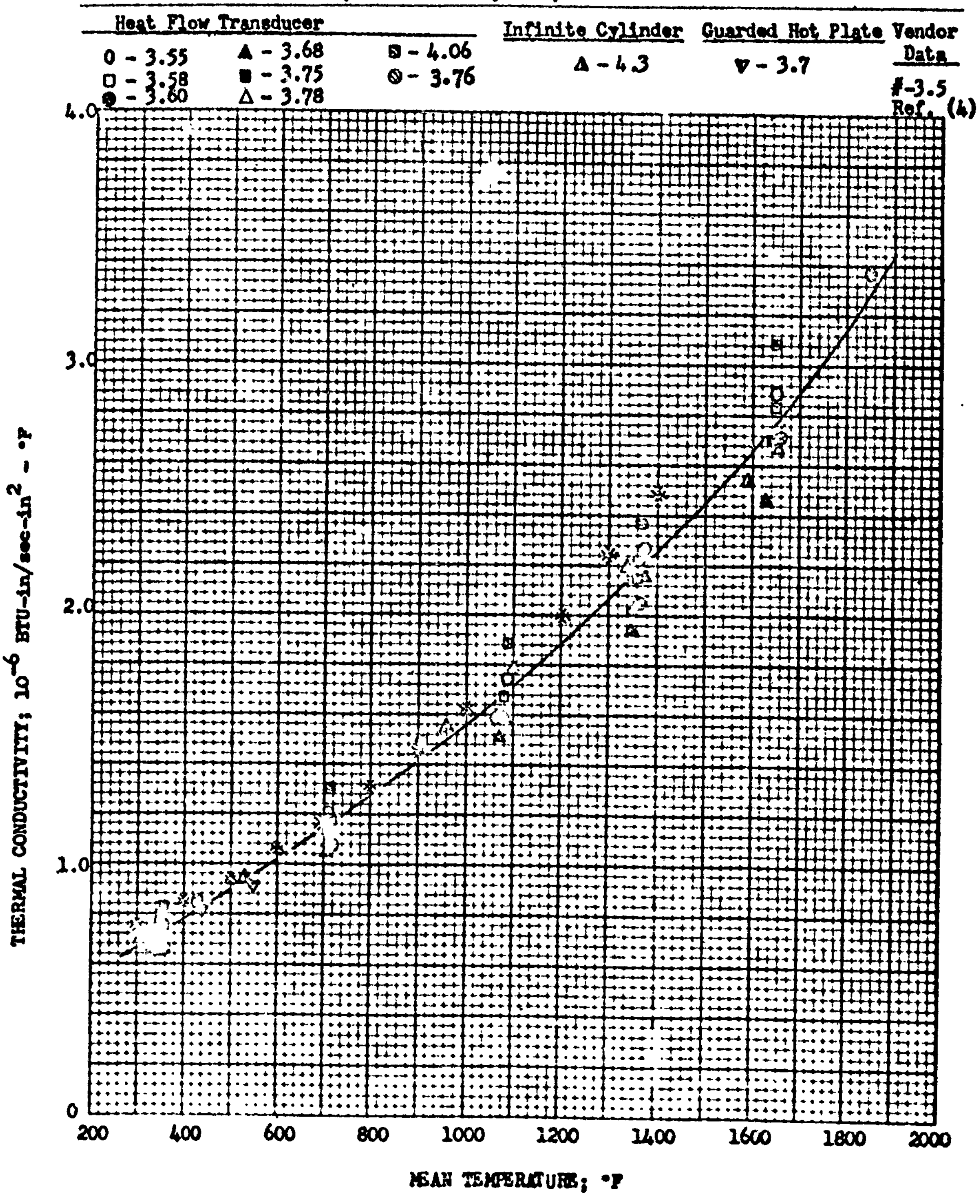
2-5332-1-08

FIGURE 14

THERMAL CONDUCTIVITY OF SEVERAL LOTS OF 3.9 ± .4 LB/FT^3 UNSTABILIZED Q-FELT

Test Pressure = Atmospheric

Specimen Density - lb/ft^3



2-3632-1-0A

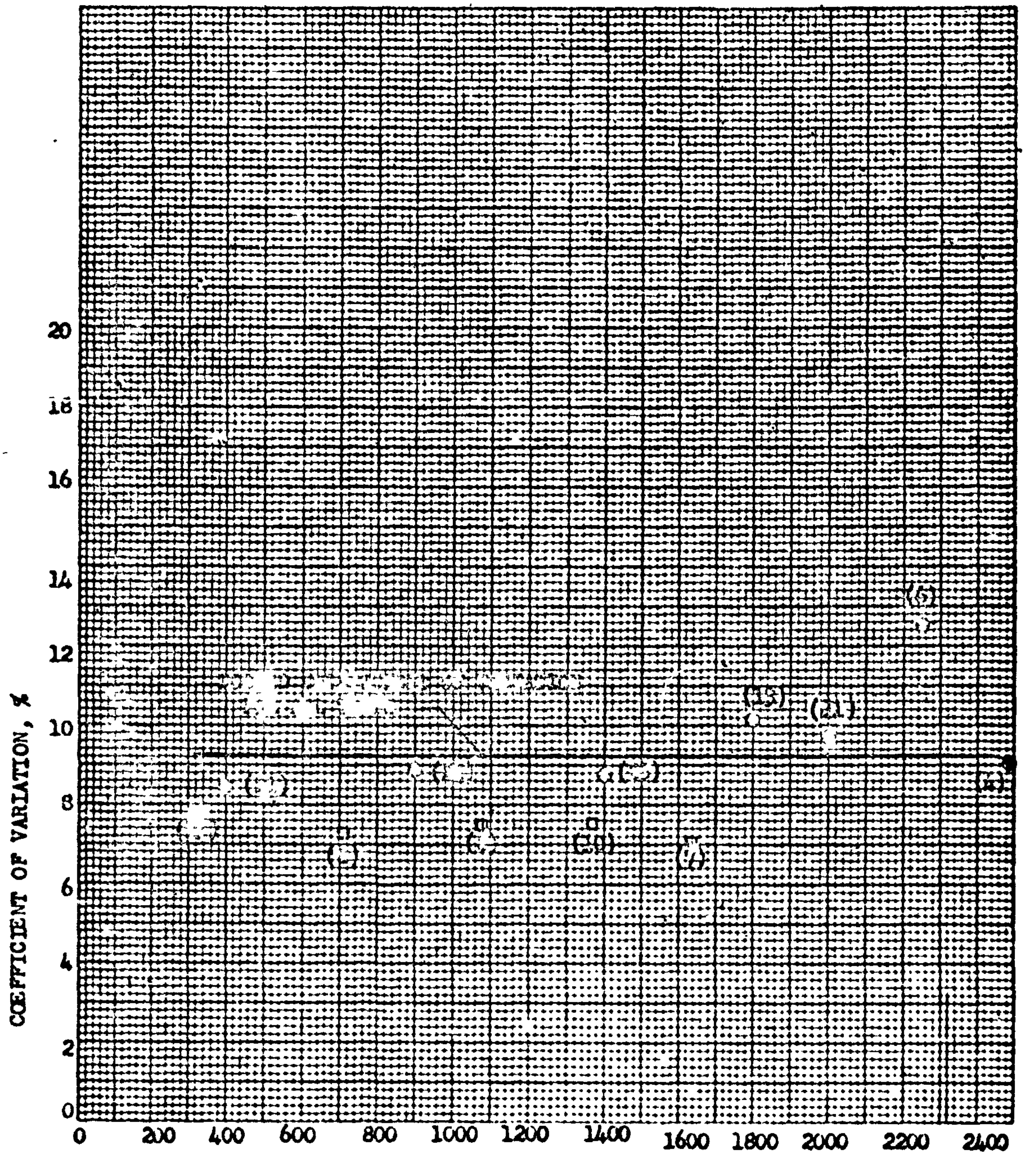
FIGURE 15

COEFFICIENT OF VARIATION OF Q-FELT THERMAL CONDUCTIVITY

● - All Q-Felt at atmospheric pressure, variation about average lines shown in Figure 8

□ - Unstabilized Q-Felt, 3.9 ± 0.4 lb/ft^3, data shown in Figure 14

( ) - Number of points included in analysis



2-5532-1-108

CONCLUSIONS

The mean apparent thermal conductivity of micro-quartz fiber insulation is a nonlinear function of the mean insulation temperature, the density of the insulation, and the pressure of the surrounding air. In general, the thermal conductivity decreases with increasing density or decreasing pressure within the ranges investigated.

Exposure of the as-produced material to temperatures much above 1800°F results in stiffening, shrinking and densification of the felt. The as-produced felt may be thermally stabilized to provide an insulation usable to considerably higher temperatures. There appears to be no significant difference in the thermal conductivity between as-produced material and thermally stabilized material when tested at identical density and pressure within the temperature range where the samples remain dimensionally stable.

Design allowable thermal conductivity values are presented as mean values with the upper and lower range stated since the application will govern whether maximum or minimum values are conservative. An estimate of the variation is included to allow the user to determine his required value.

The allowable curves for unstabilized material are limited to mean temperatures below 1800°F due to dimensional instability above this temperature. These curves are presented as a function of mean temperature at various pressures for 3.6, 5.1, and 7.3 lb/ft^3 densities in Figure 16 through 18.

The allowable curves for thermally stabilized material cover temperatures to 2500°F. These curves are also presented as a function of mean temperature at various pressures for three densities, 4.5, 6.2, and 8.0 lb/ft^3, as shown in Figure 19 through 21.

FIGURE 16

ALLOWABLE THERMAL CONDUCTIVITY FOR 3.6 LB/FT^3 MICRO-QUARTZ FIBER INSULATION

Q-Felt (BMS 9-1, Type I)

0.50 in. thick

UNSTABILIZED

Test Condition: Thermal Equilibrium in air

For maximum or minimum values, adjust the mean thermal conductivity values as follows:

Reliability	Upper Limit	Lower Limit
$C_{.95} - P_{.90}$	1.14 x Mean	.86 x Mean
$C_{.95} - P_{.99}$	1.25 x Mean	.75 x Mean

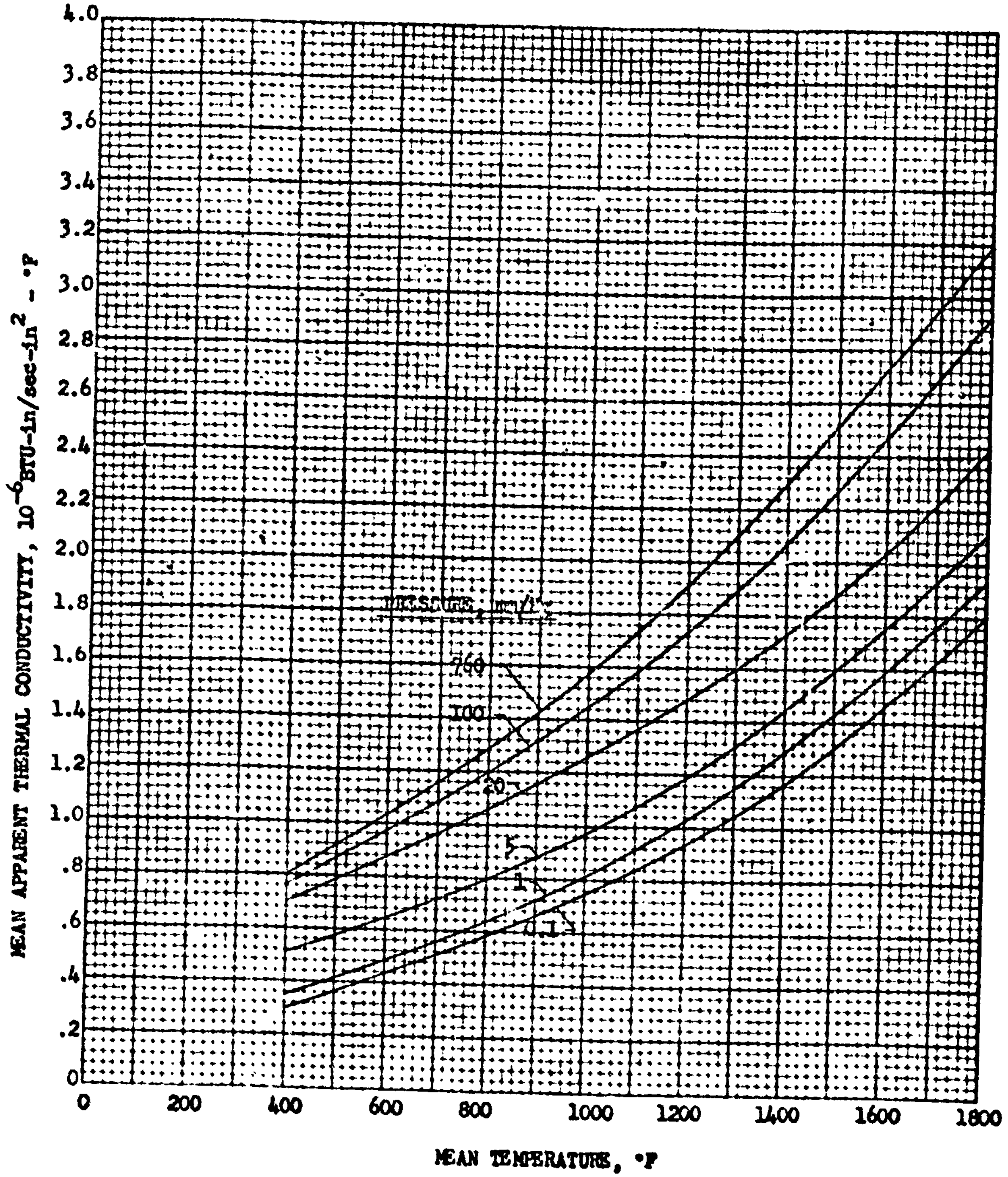


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FIGURE 17

ALLOWABLE THERMAL CONDUCTIVITY FOR 5.1 LB/FT^3 MICRO-QUARTZ FIBER INSULATION

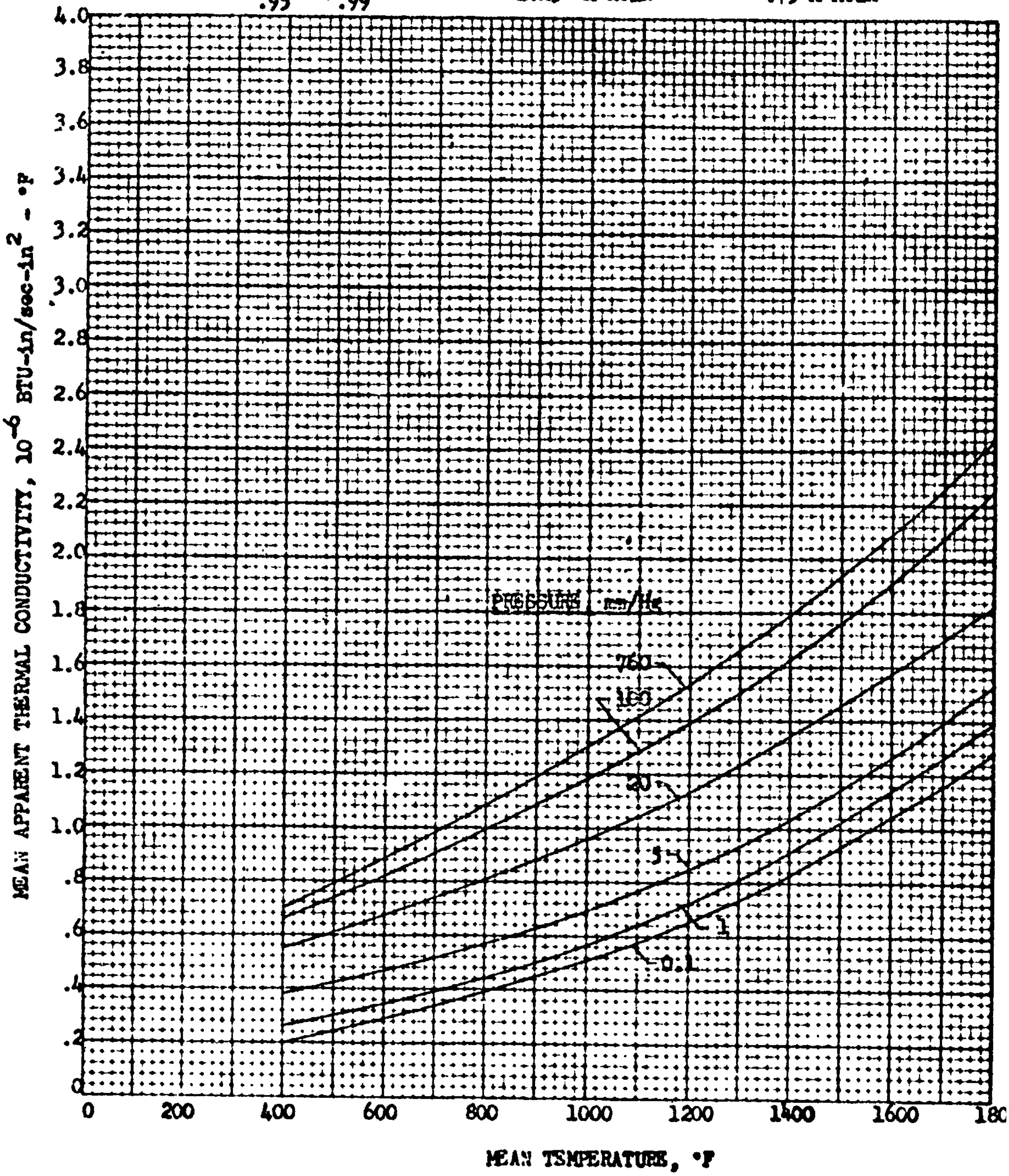
Q-Felt (BMS 9-1 Type I) 0.50 in thick

UNSTABILIZED

Test Condition: Thermal Equilibrium in Air

For maximum or minimum values, adjust the mean thermal conductivity values as follows:

Reliability	Upper Limit	Lower Limit
$C_{.95} - P_{.90}$	1.14 x Mean	.86 x Mean
$C_{.95} - P_{.99}$	1.25 x Mean	.75 x Mean



2-5532--0A

FIGURE 18

ALLOWABLE THERMAL CONDUCTIVITY FOR 7.3 LB/FT^3 MICRO-QUARTZ FIBER INSULATION

Q-Felt (BMS 9-1 Type I) 0.50 in thick

UNSTABILIZED

Test Condition: Thermal Equilibrium in Air

For maximum or minimum values, adjust the mean thermal conductivity values as follows:

Reliability	Upper Limit	Lower Limit
$C_{.95} - P_{.90}$	1.14 x Mean	.86 x Mean
$C_{.95} - P_{.99}$	1.25 x Mean	.75 x Mean

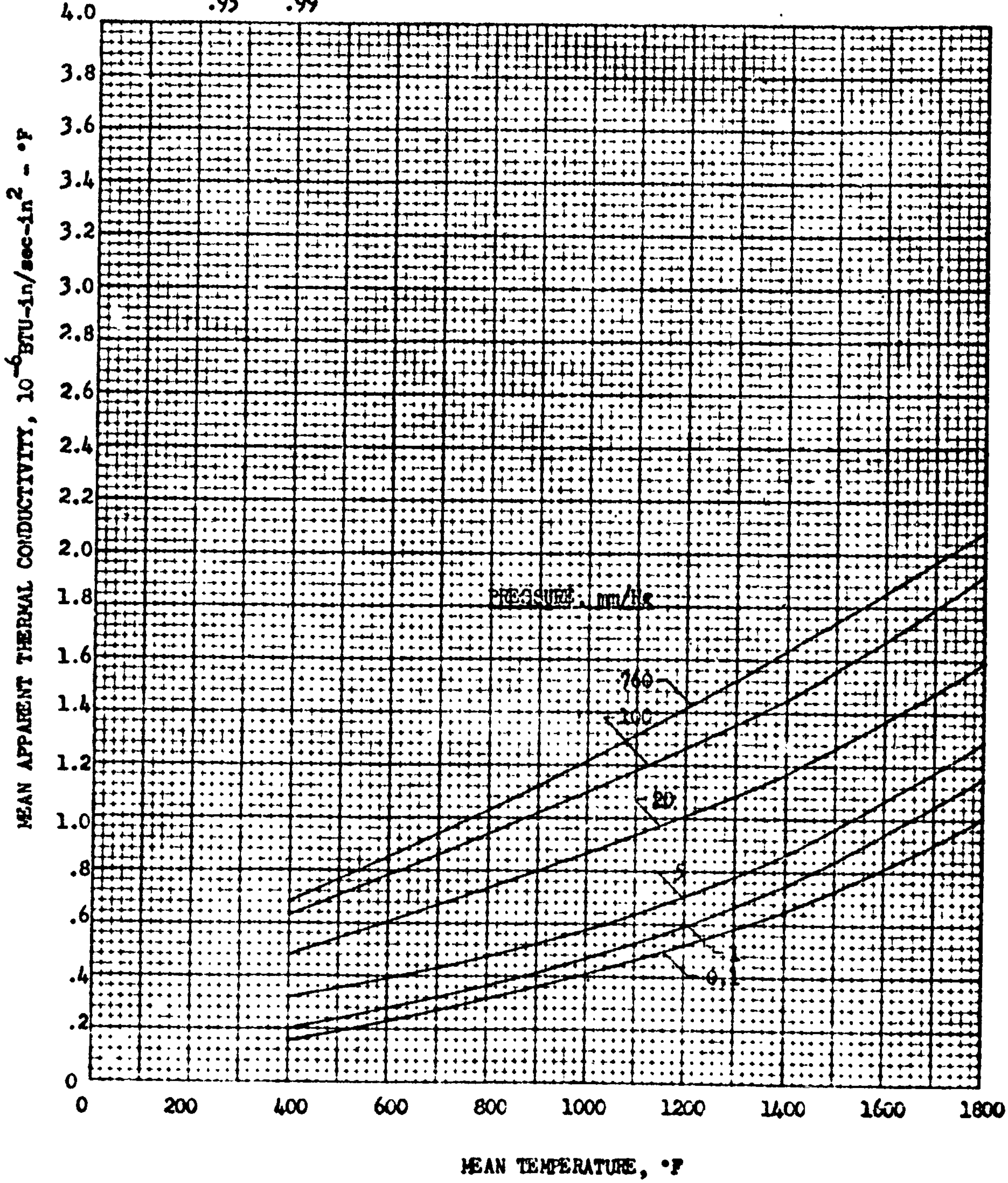


FIGURE 19

ALLOWABLE THERMAL CONDUCTIVITY FOR 4.5 LB/FT^3 MICRO-QUARTZ FIBER INSULATION

Q-Felt (BMS 9-1 Type II) 0.25 in thick

Thermally Stabilized 3 Hours at 2200°F

Test Condition: Thermal Equilibrium in Air

For maximum or minimum values, adjust the mean thermal conductivity values as follows:

Reliability	Upper Limit	Lower Limit
$C_{.95} - P_{.90}$	1.14 x Mean	.86 x Mean
$C_{.95} - P_{.99}$	1.25 x Mean	.75 x Mean

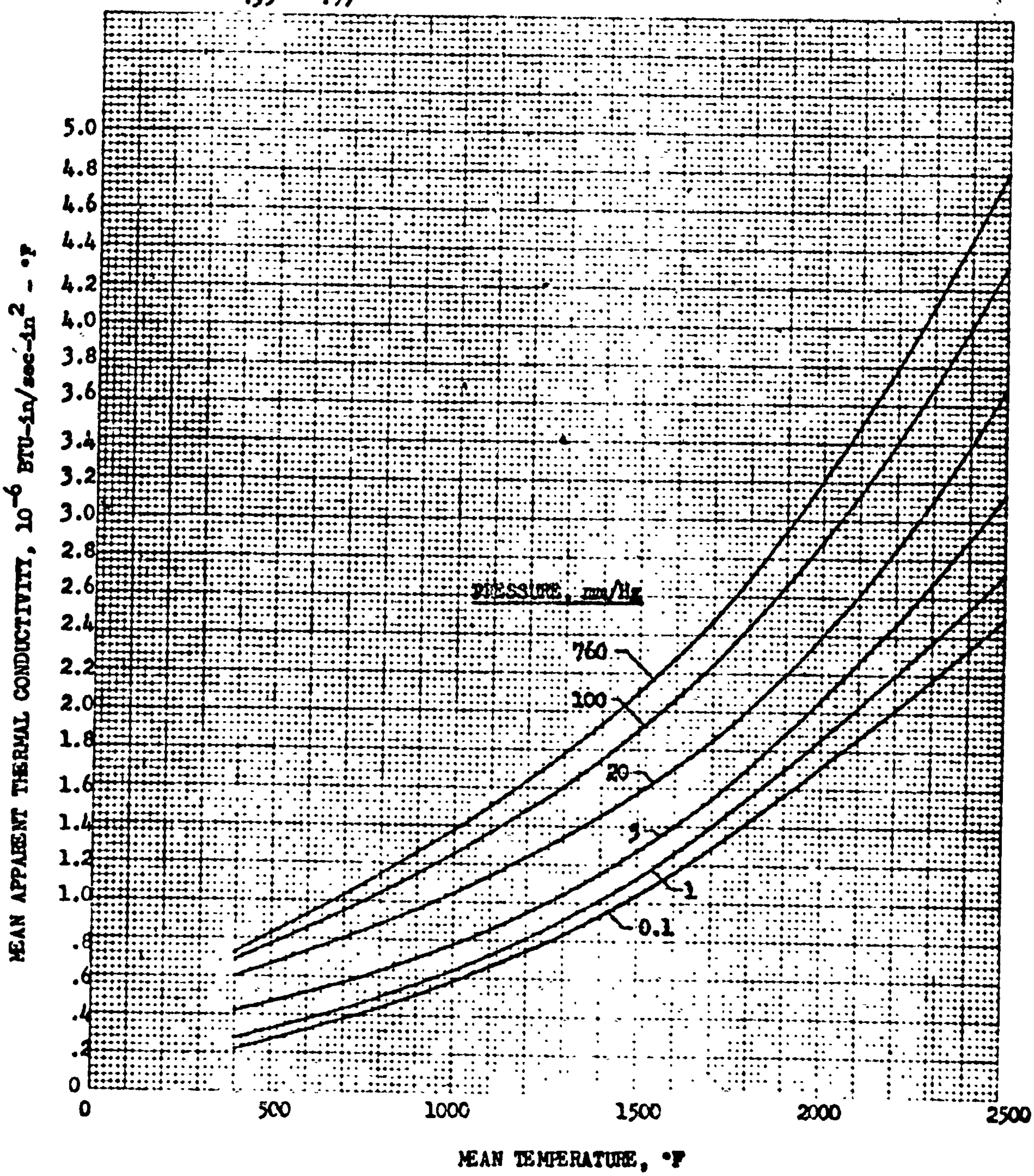


FIGURE 20

ALLOWABLE THERMAL CONDUCTIVITY FOR 6.2 LB/FT^3 MICRO-QUARTZ FIBER INSULATION

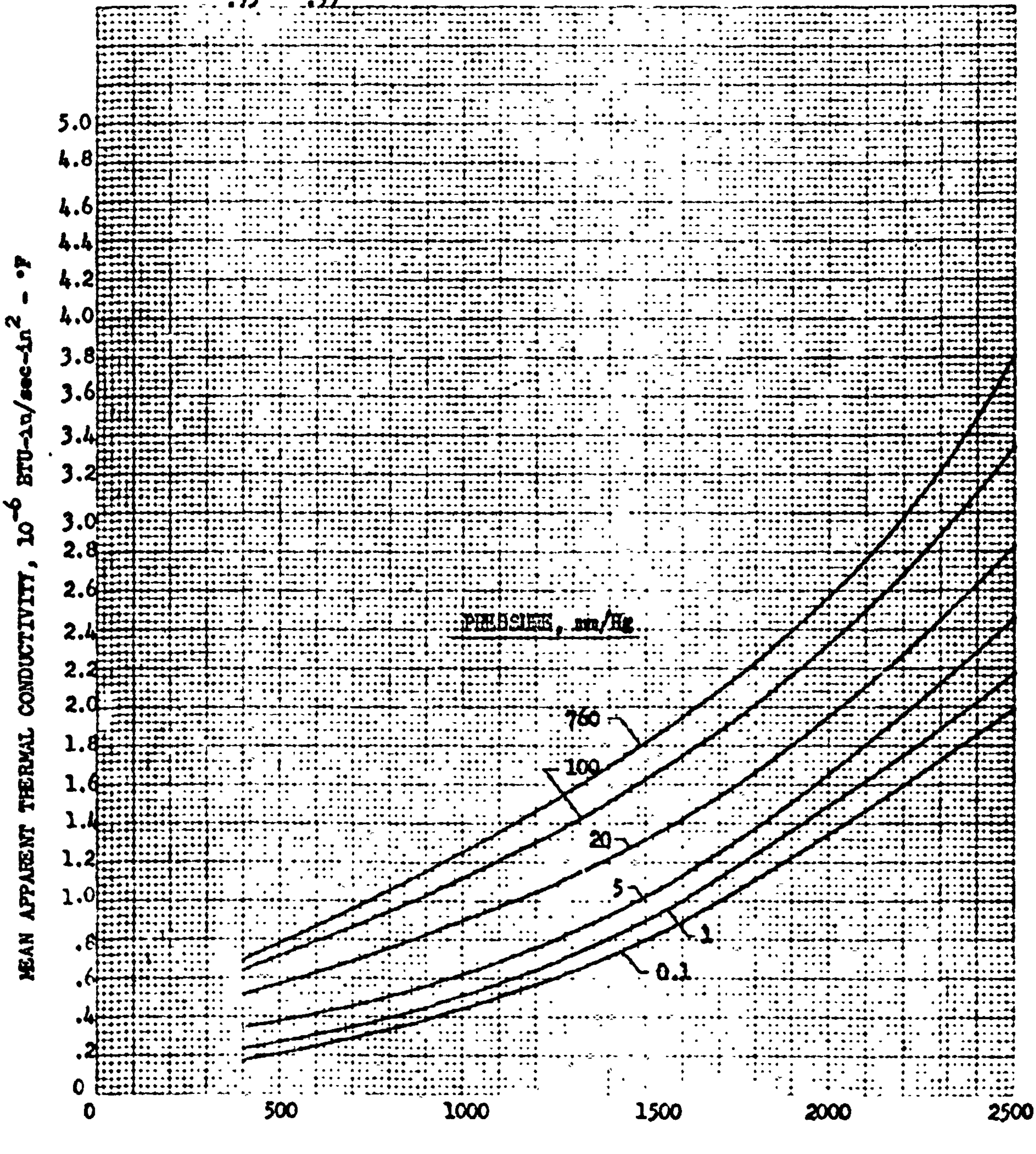
Q-Felt (BMS 9-1 Type II) 0.25 in. thick

Thermally Stabilized 3 Hours at 2200°F

Test Condition: Thermal Equilibrium in Air

For maximum or minimum values, adjust the mean thermal conductivity values as follows:

Reliability	Upper Limit	Lower Limit
$C_{.95} - P_{.90}$	1.14 x Mean	.86 x Mean
$C_{.95} - P_{.99}$	1.25 x Mean	.75 x Mean



2-5532- -08

FIGURE 21

ALLOWABLE THERMAL CONDUCTIVITY FOR 8.0 LB/FT^3 MICRO-QUARTZ FIBER INSULATION

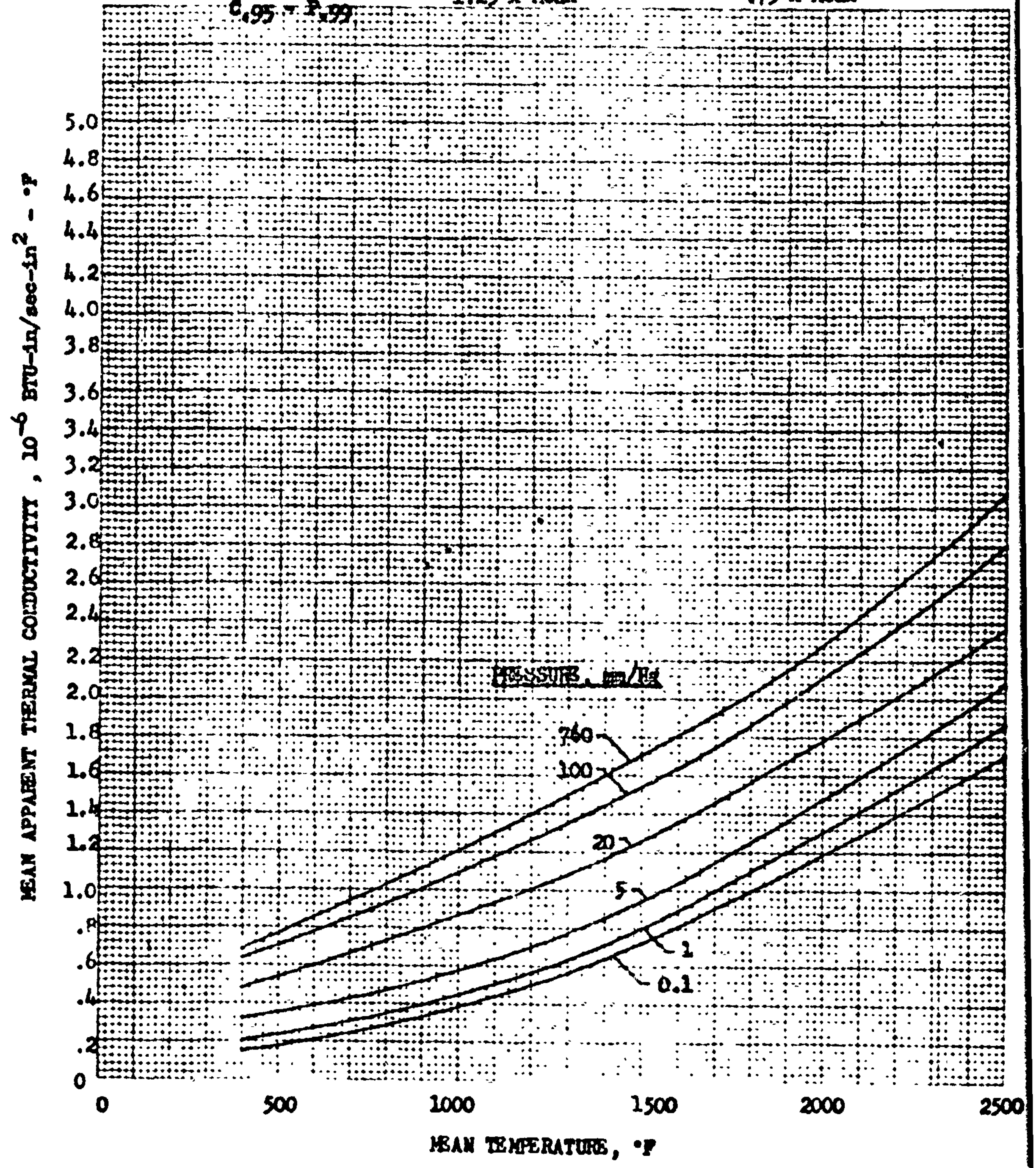
Q-Felt (BMS 9-1 Type II) 0.25 in. thick

Thermally Stabilized 3 hours at 220°F

Test Condition: Thermal Equilibrium in Air

For maximum or minimum values, adjust the mean thermal conductivity values as follows:

Reliability	Upper Limit	Lower Limit
$C_{.95} - P_{.90}$	1.14 x Mean	.86 x Mean
$C_{.95} - P_{.99}$	1.25 x Mean	.75 x Mean



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APPENDIX A

TEST DATA PLOTS AND NOMINAL CURVES

Included in this appendix are plots of actual test data for the various specimens tested in this program and also for referenced data used in the analysis provided in the text of this document.

These data were plotted as a function of temperature and test pressure and curves were faired through the data points to define the nominal temperature-pressure influence on the measured thermal conductivity of the various specimens.

Figures A-1 through A-12 cover unstabilized material and Figures A-13 through A-24 cover the thermally stabilized material. The figures are arranged in order of increasing specimen density for each material condition.

FIGURE A-1

VENDOR INFORMATION ON 3.0 TO 3.5 LB/FT^3 UNSTABILIZED Q-FELT

pressure = atmospheric

O - 3.0 lb/ft^3 density, 3/16 in. thickness

Data per Ref. (4)

□ - 3.5 lb/ft^3 density, ½ in. thickness

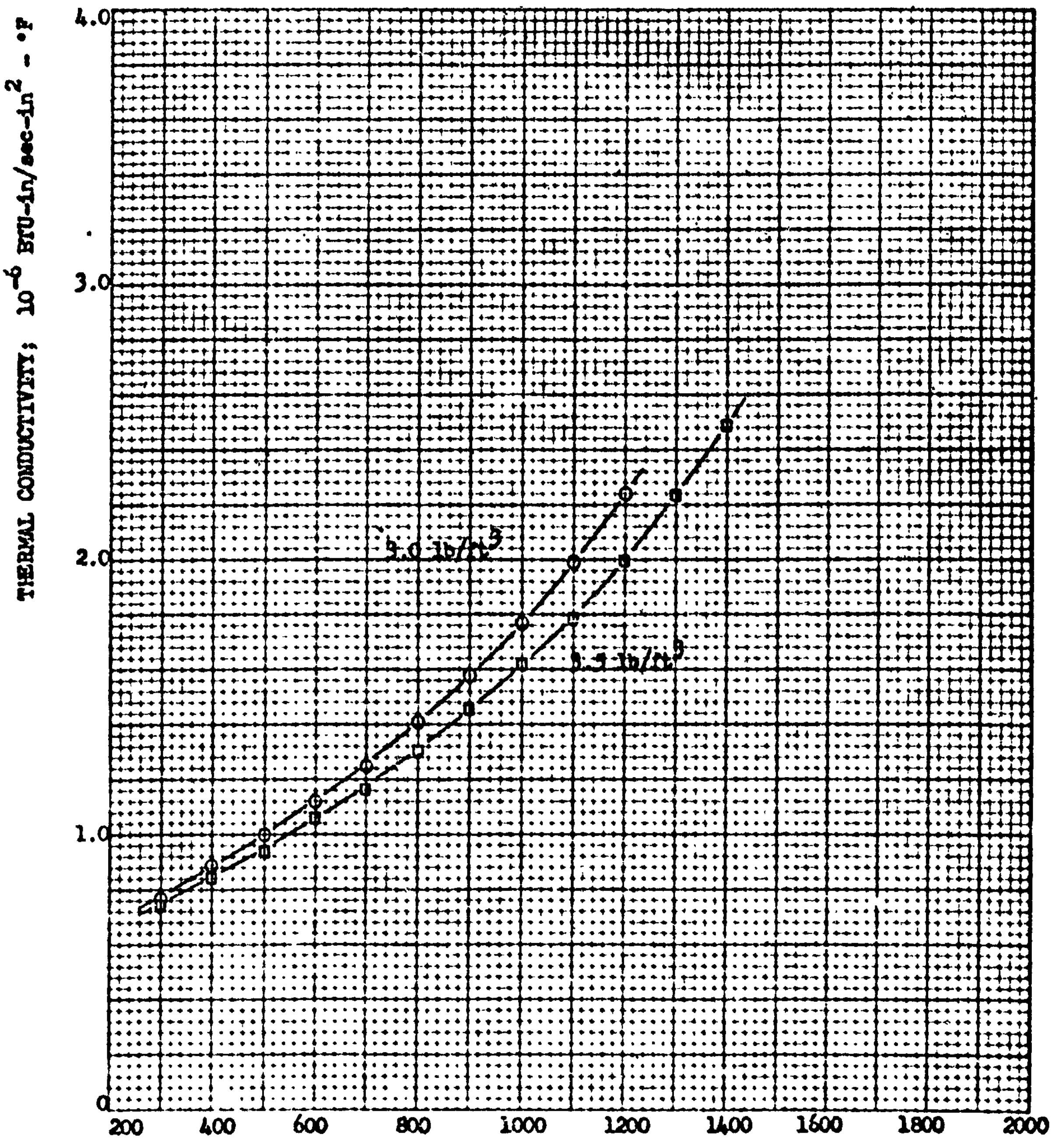

FIGURE A-2

TEMPERATURE EFFECT ON 3.55-4.06 LB/FT^3 UNSTABILIZED Q-FELT FROM LOT D

Specimen Density, lb/ft^3

o - 3.55   △ - 3.78
□ - 3.58   ⊠ - 4.06
⊘ - 3.76

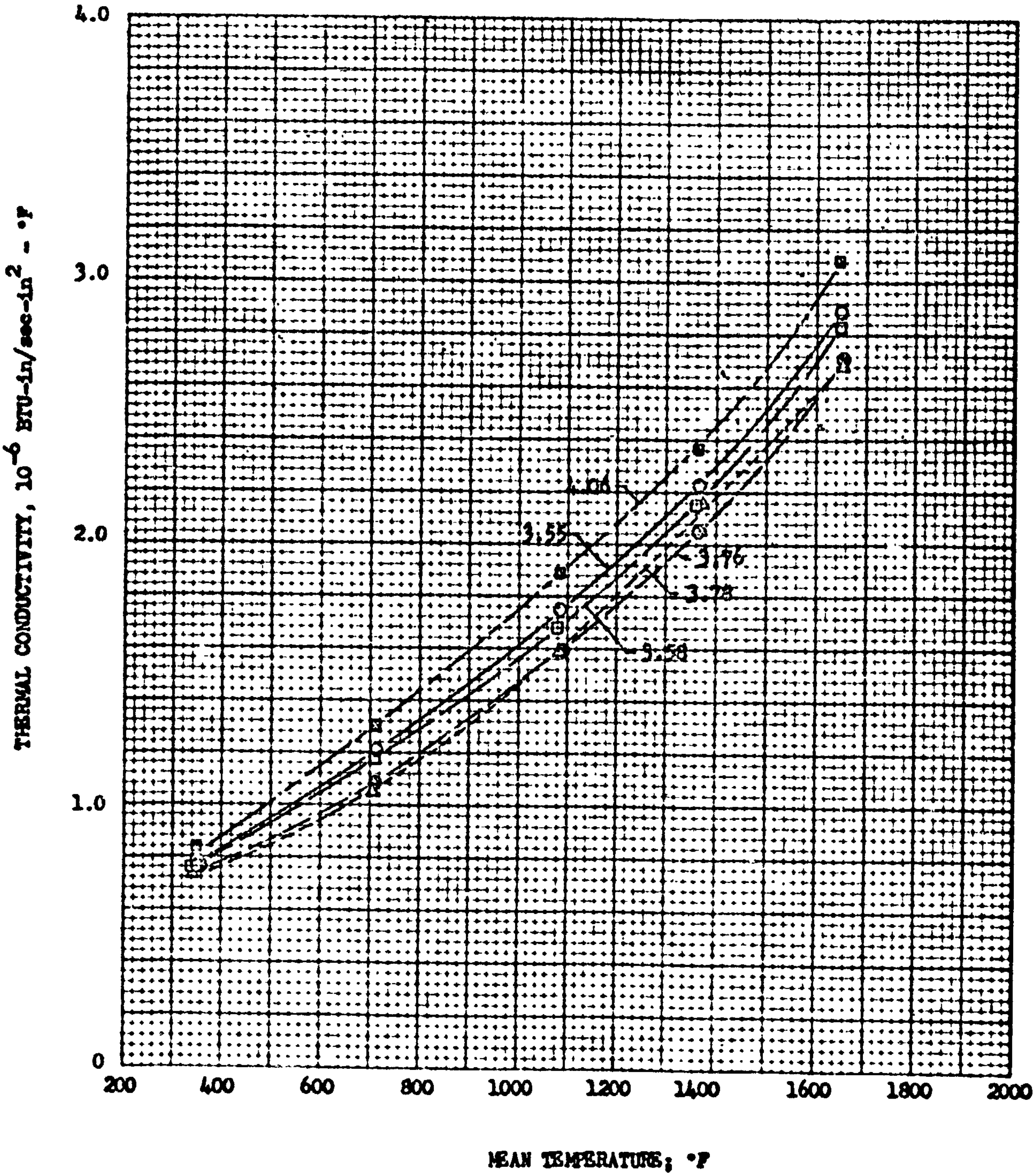

FIGURE A-3

TEMPERATURE EFFECT ON 3.6 LB/FT^3 UNSTABILIZED Q-FELT

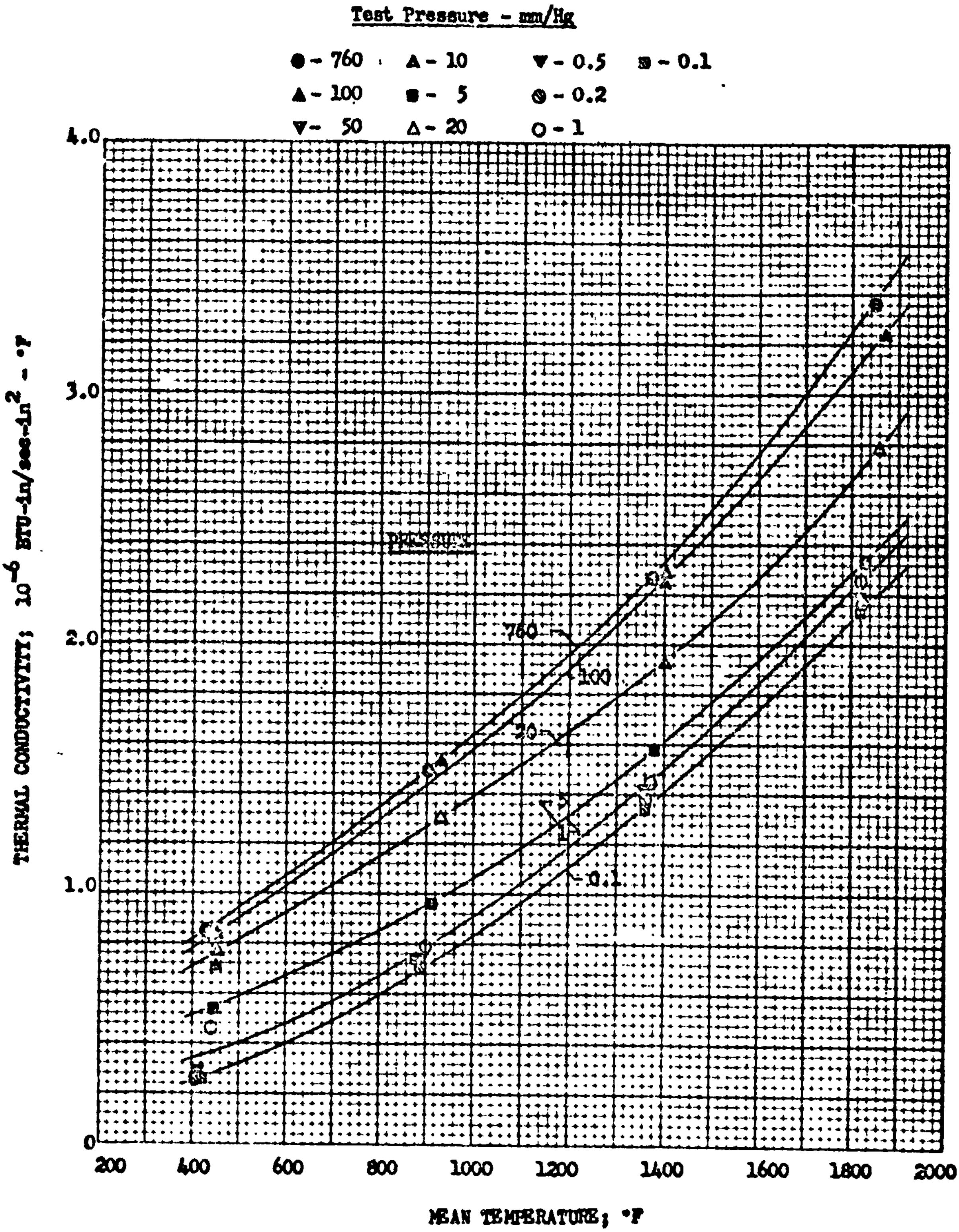

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FIGURE 4-4

PRESSURE EFFECT ON 3.6 LB/FT^3 UNSTABILIZED Q-FELT

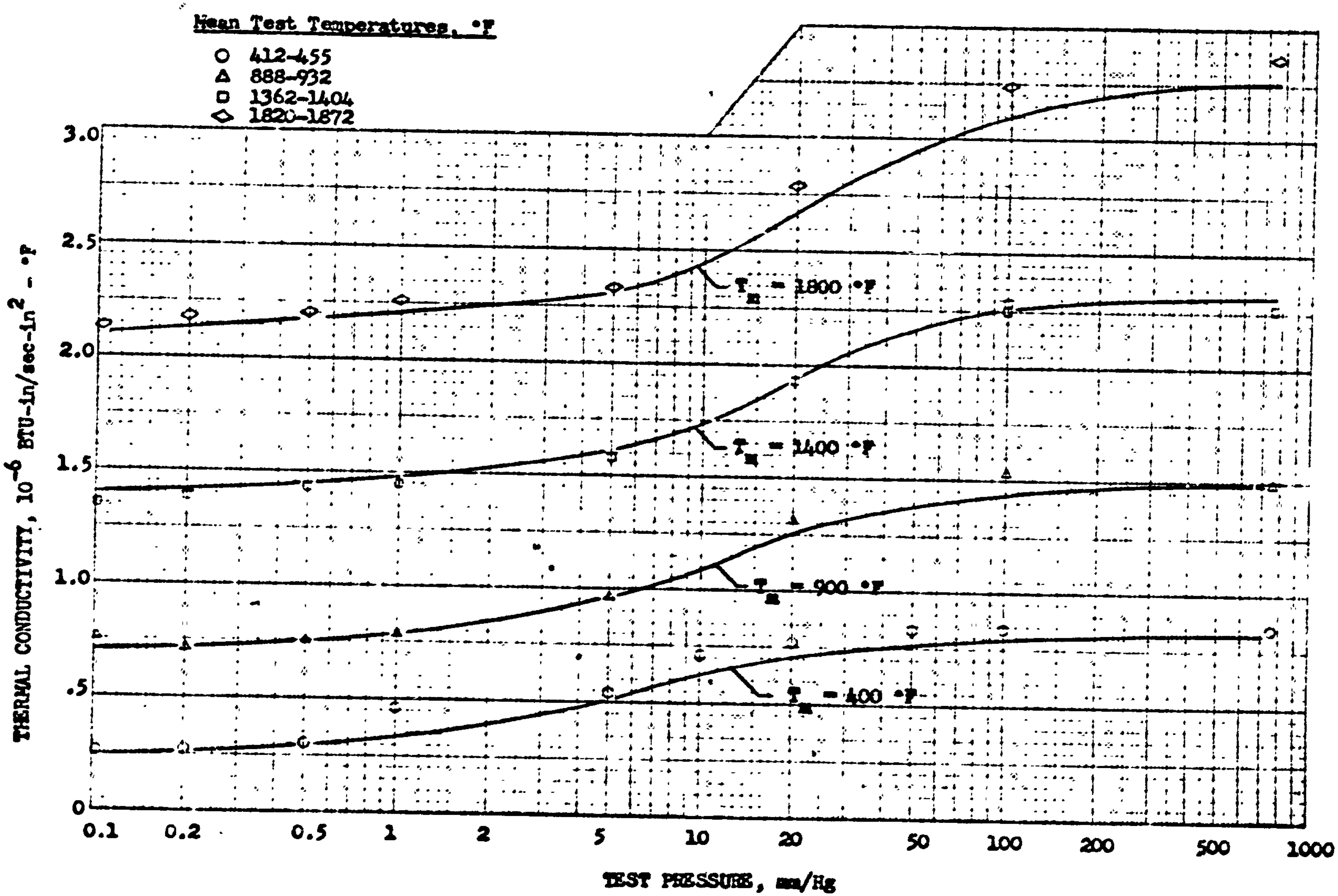


FIGURE A-5

TEMPERATURE EFFECT ON 3.68 AND 3.75 LB/FT^3 UNSTABILIZED Q-FELT FROM LOT E

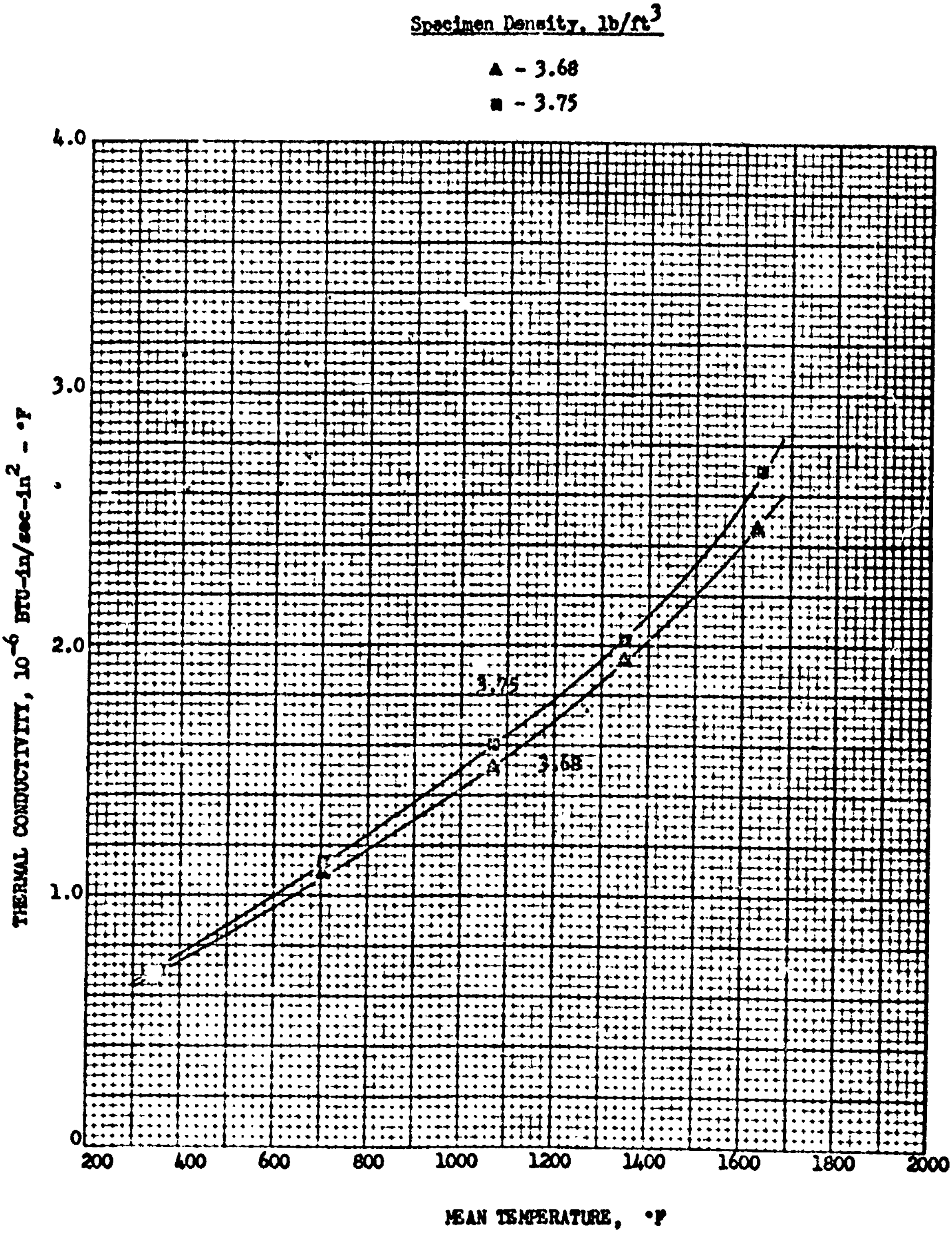
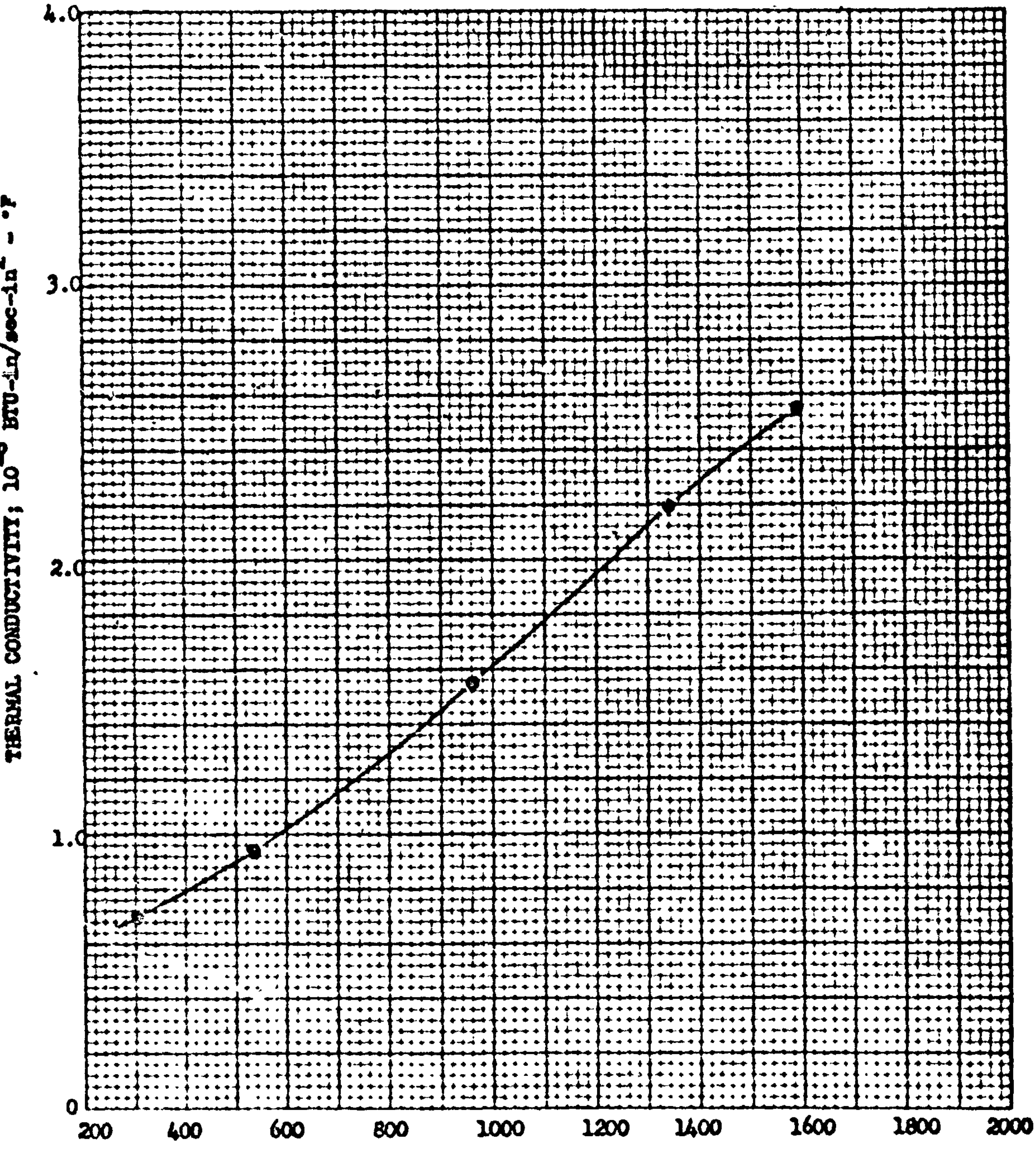


FIGURE A-6

TEMPERATURE EFFECT ON 4.3 LB/FT^3 UNSTABILIZED Q-FELT

Test Pressure = 760 mm/Hg



2-5652- - 3A

FIGURE A-7

TEMPERATURE EFFECT ON 5.1 LB/FT^3 UNSTABILIZED Q-FELT

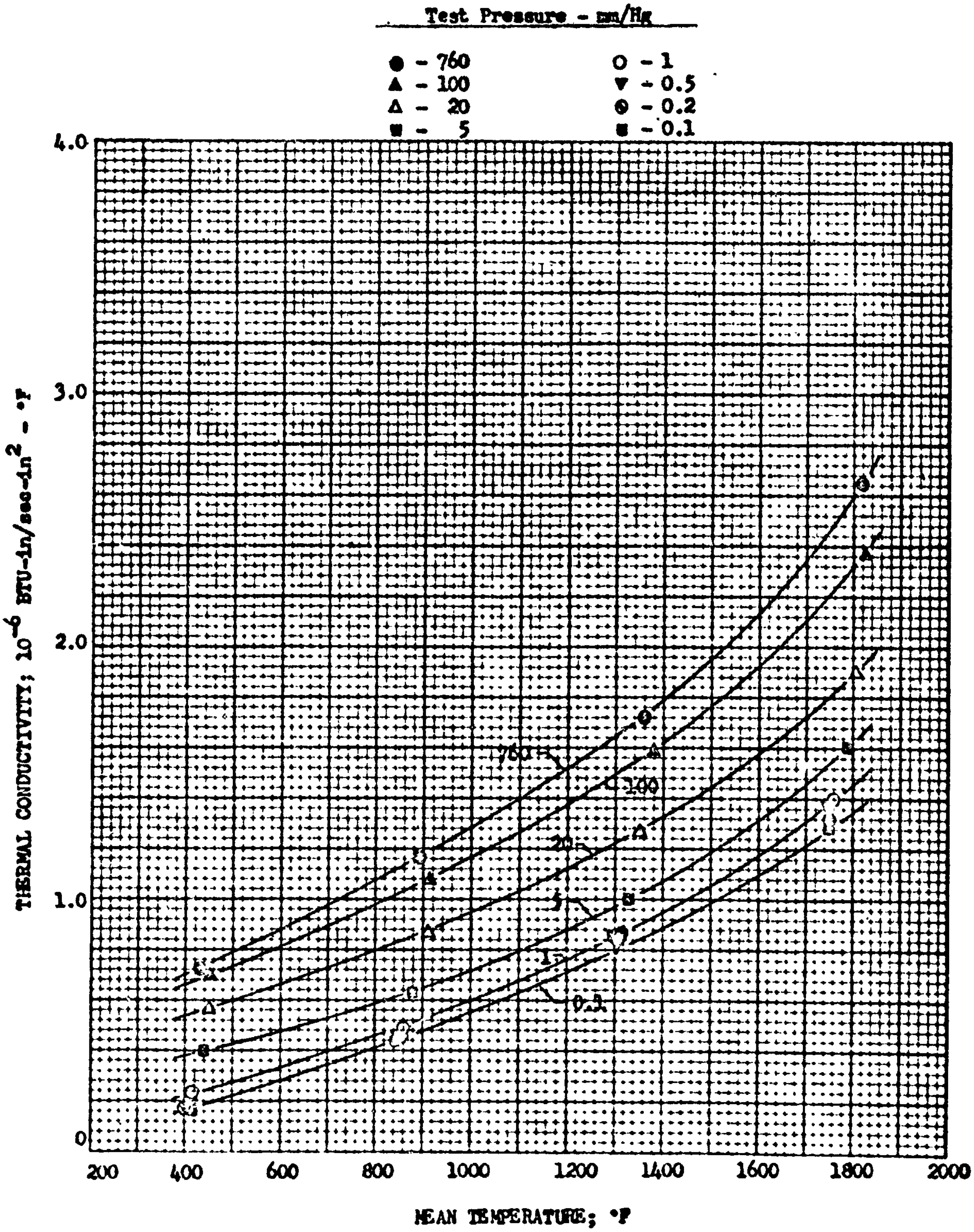


FIGURE A-8

PRESSURE EFFECT ON 5.1 LB/FT^3 UNSTABILIZED Q-FELT

<u>Mean Test Temperature, °F</u>

○	401-454
△	851-913
□	1309-1381
◇	1751-1824

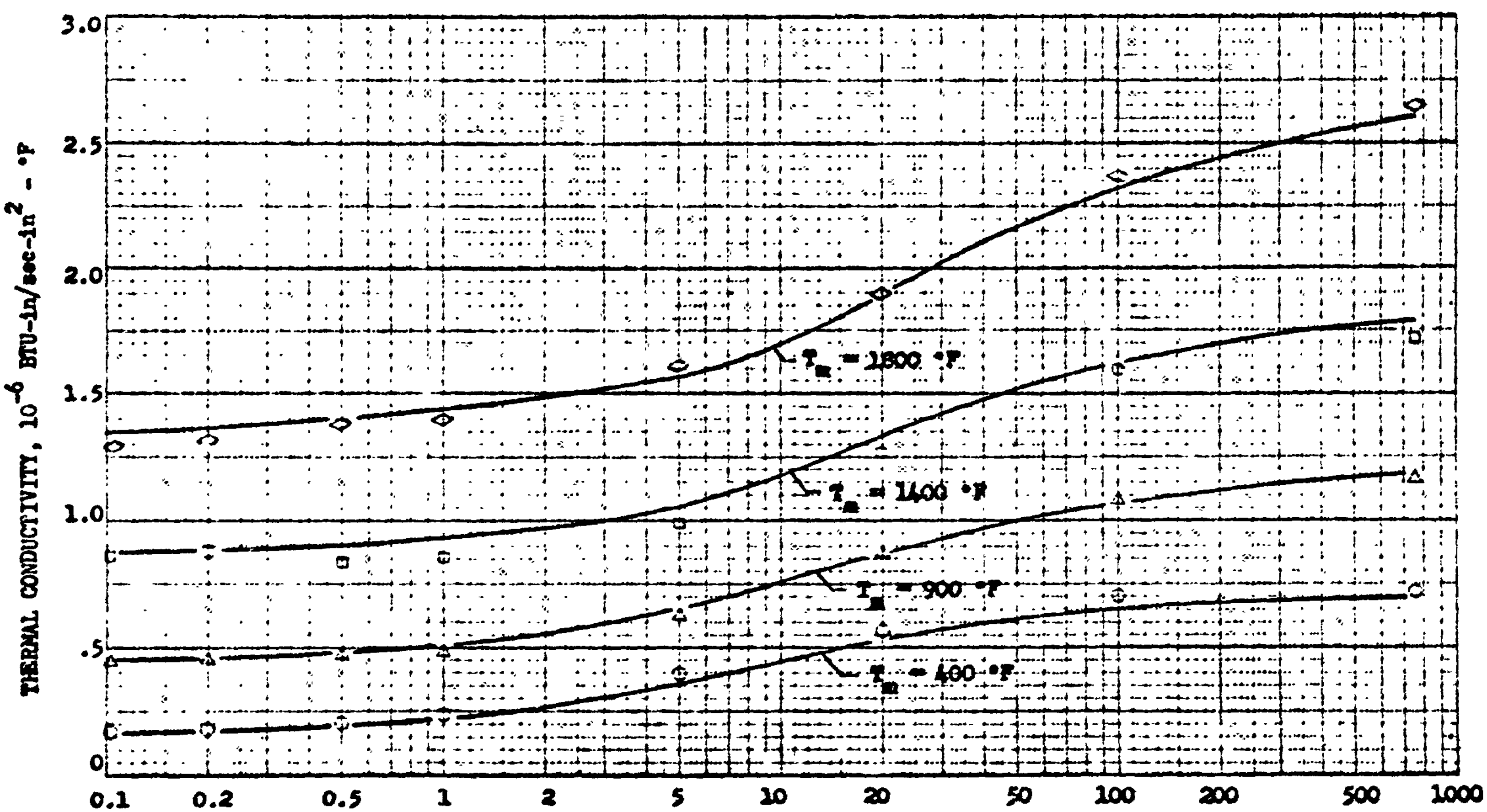
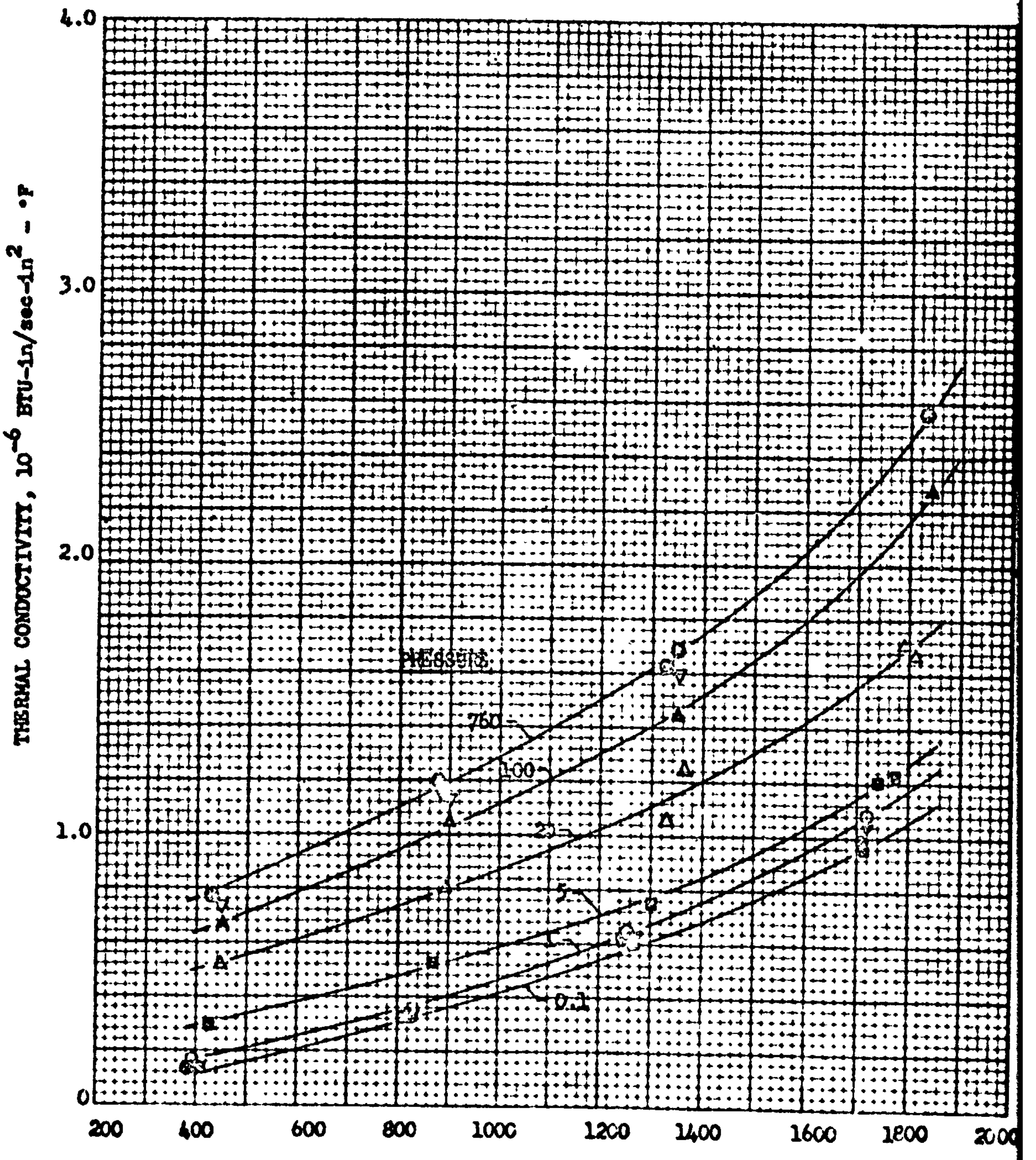


FIGURE A-9

TEMPERATURE EFFECT ON 7.3 LB/FT^3 UNSTABILIZED Q-FELT

Test Pressure, mm/Hg

● - 760　　△ - 20　　▼ - 0.5
▽ - 300　　■ - 5　　⊘ - 0.2
▲ - 100　　O - 1　　⧅ - 0.1



2-5632--OA

FIGURE A-10

PRESSURE EFFECT ON 7.3 LB/FT^3 UNSTABILIZED Q-FELT

Mean Test Temperature, °F

O - 382-448 □ - 1263-1366
Δ - 818-899 ◇ - 1710-1842

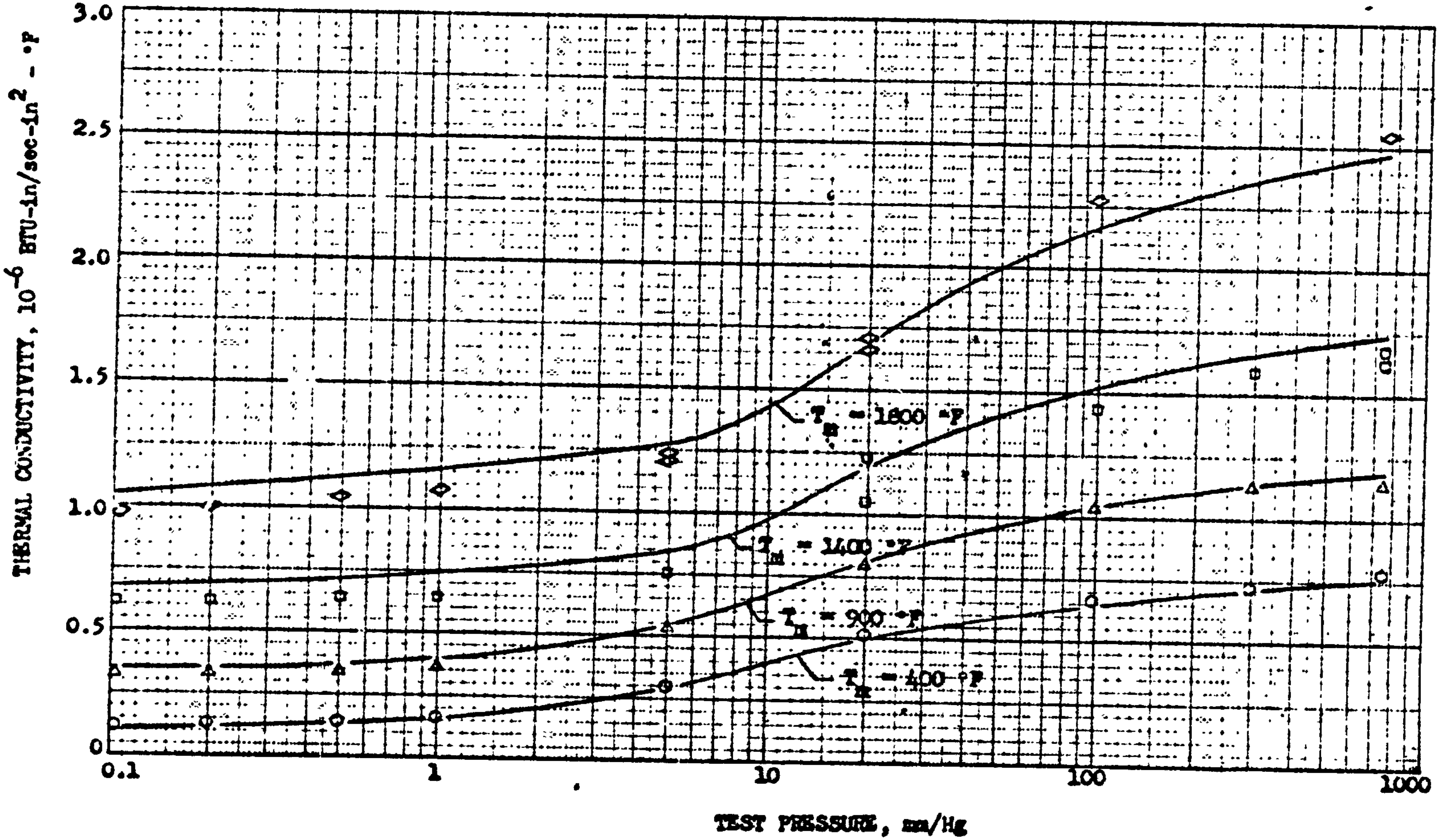
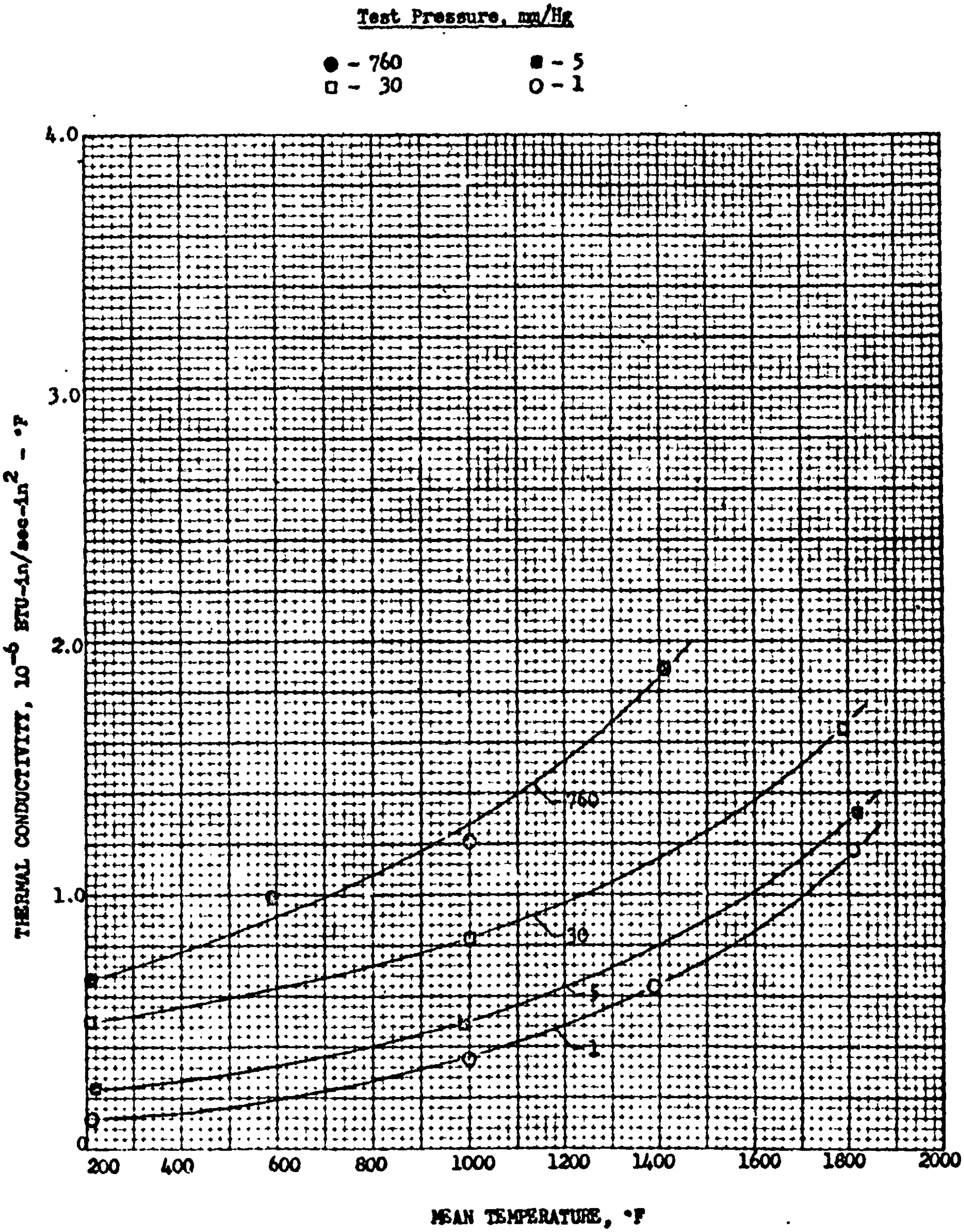


FIGURE A-11

TEMPERATURE EFFECT ON 7.5 LB/FT^3 UNSTABILIZED Q-FELT



2-5632-~0A

FIGURE A-12

PRESSURE EFFECT ON 7.5 LB/FT^3 UNSTABILIZED Q-FELT

Mean Test Temperature, °F

▽	200-217	□	1388-1410
O	989-1002	◇	1789-1818

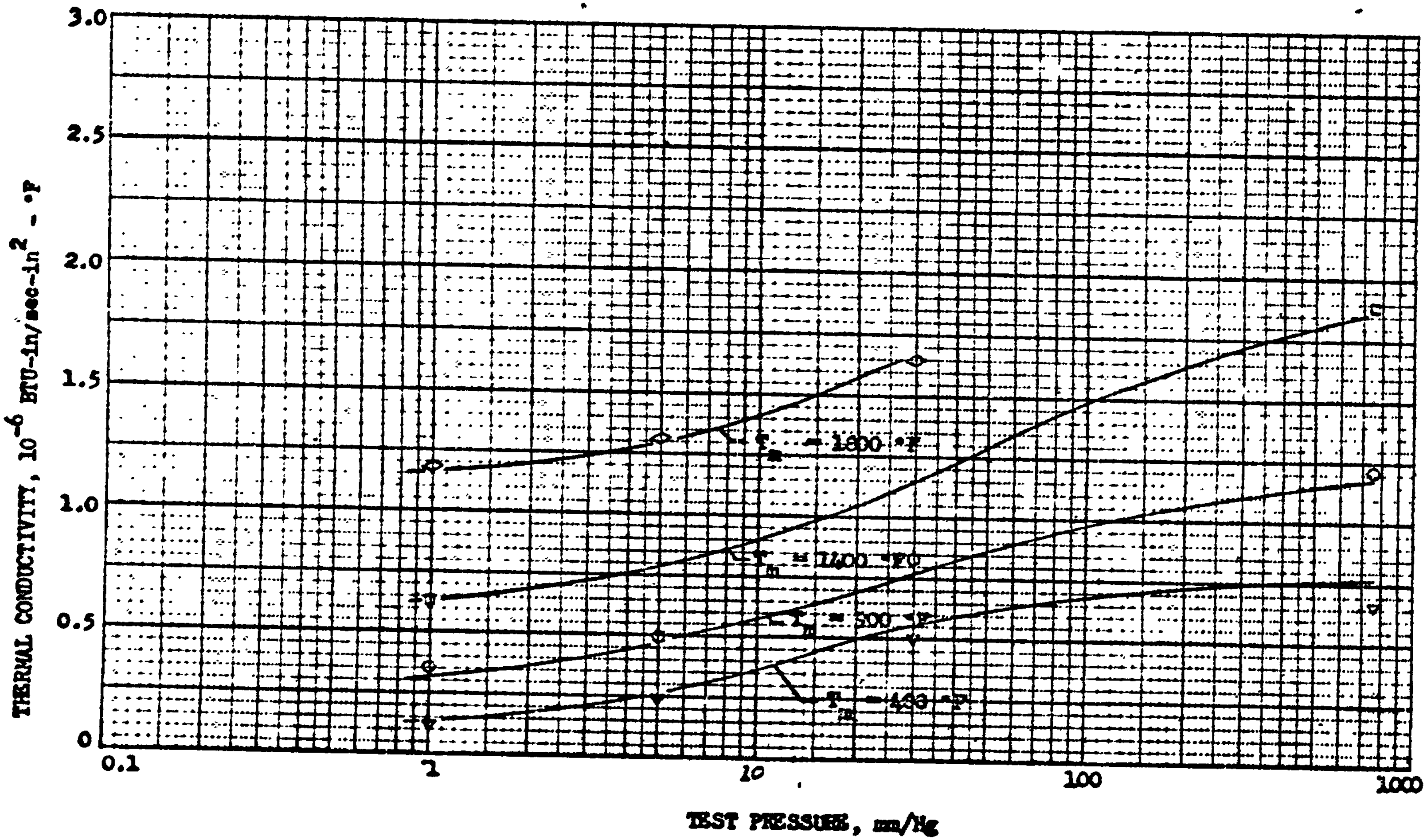


FIGURE A-13

VENDOR INFORMATION ON 4.5 TO 10.0 LB/FT^3 THERMALLY STABILIZED Q-FELT

Pressure = atmospheric

▽ - 4.5 lb/ft^3 density
O - 6.2 lb/ft^3 density
□ - 8.0 lb/ft^3 density
△ - 10.0 lb/ft^3 density

Data per Ref. (3)

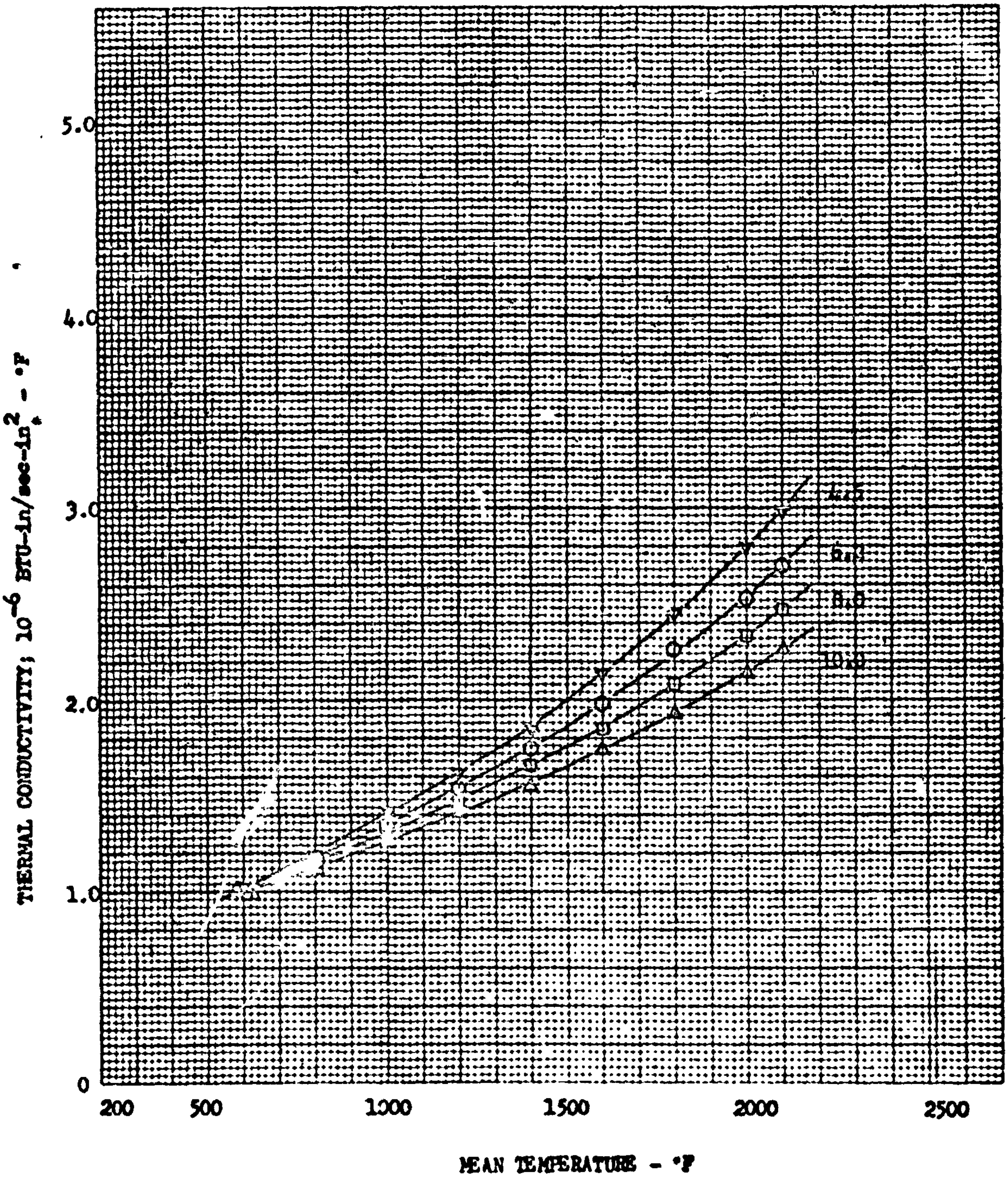
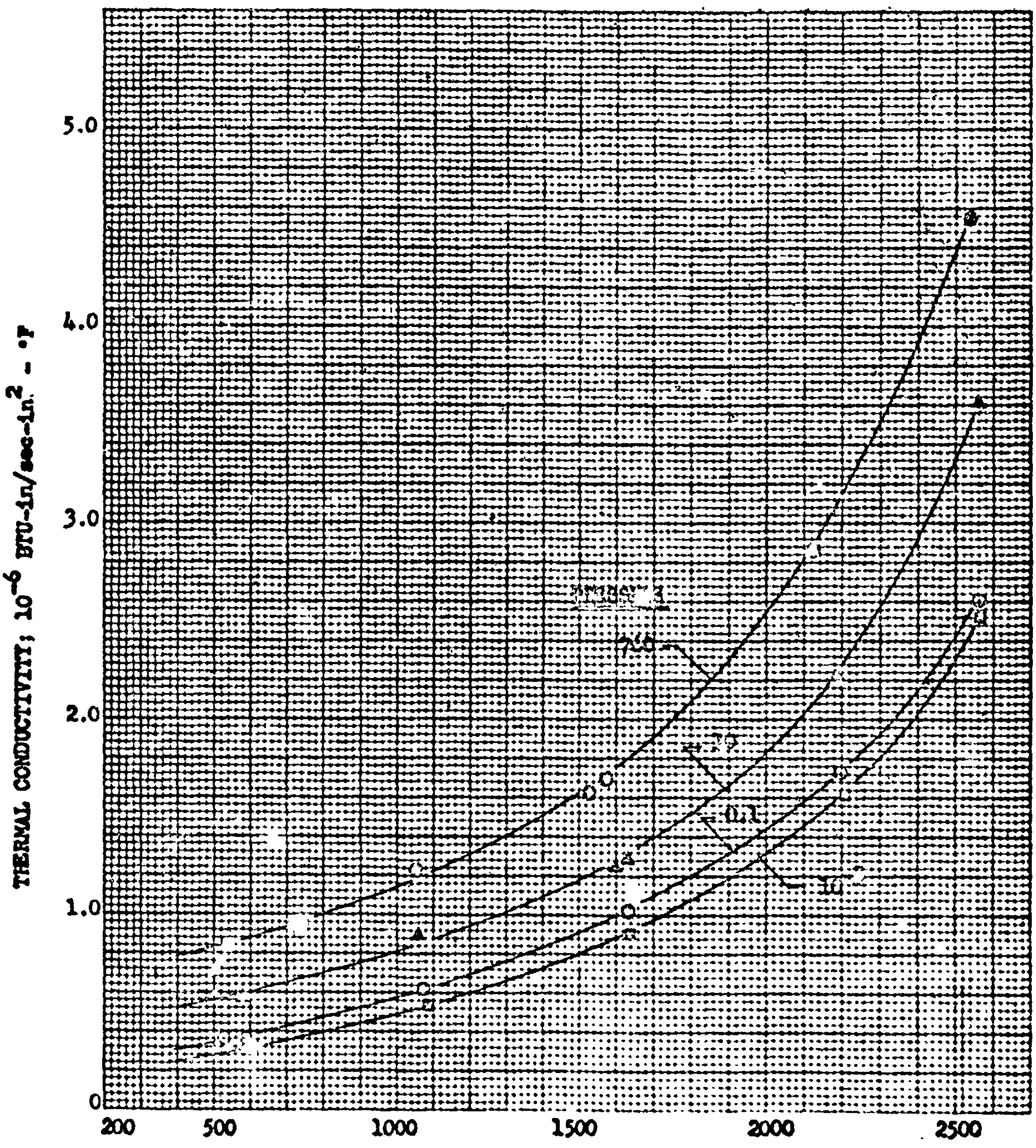


FIGURE A-14

REFERENCED TEST DATA ON 4.58 LB/FT^3 THERMALLY STABILIZED Q-FELT, TEMP. EFFECT

Test Pressure   Data per Ref. (6)

● - 760 mm/Hg
▲ - 10 mm/Hg
0 - 0.1 mm/Hg
■ - 10^{-3} mm/Hg



2-5532-...-78

FIGURE A-15

REFERENCED TEST DATA ON 4.58 LB/FT^3 THERMALLY STABILIZED MATERIAL, PRESSURE EFFECT

Data per Ref. (6)

Mean Test Temperature, °F			
O	526-591	◇	2124-2198
□	1057-1076	▽	2542-2562
△	1575-1636		

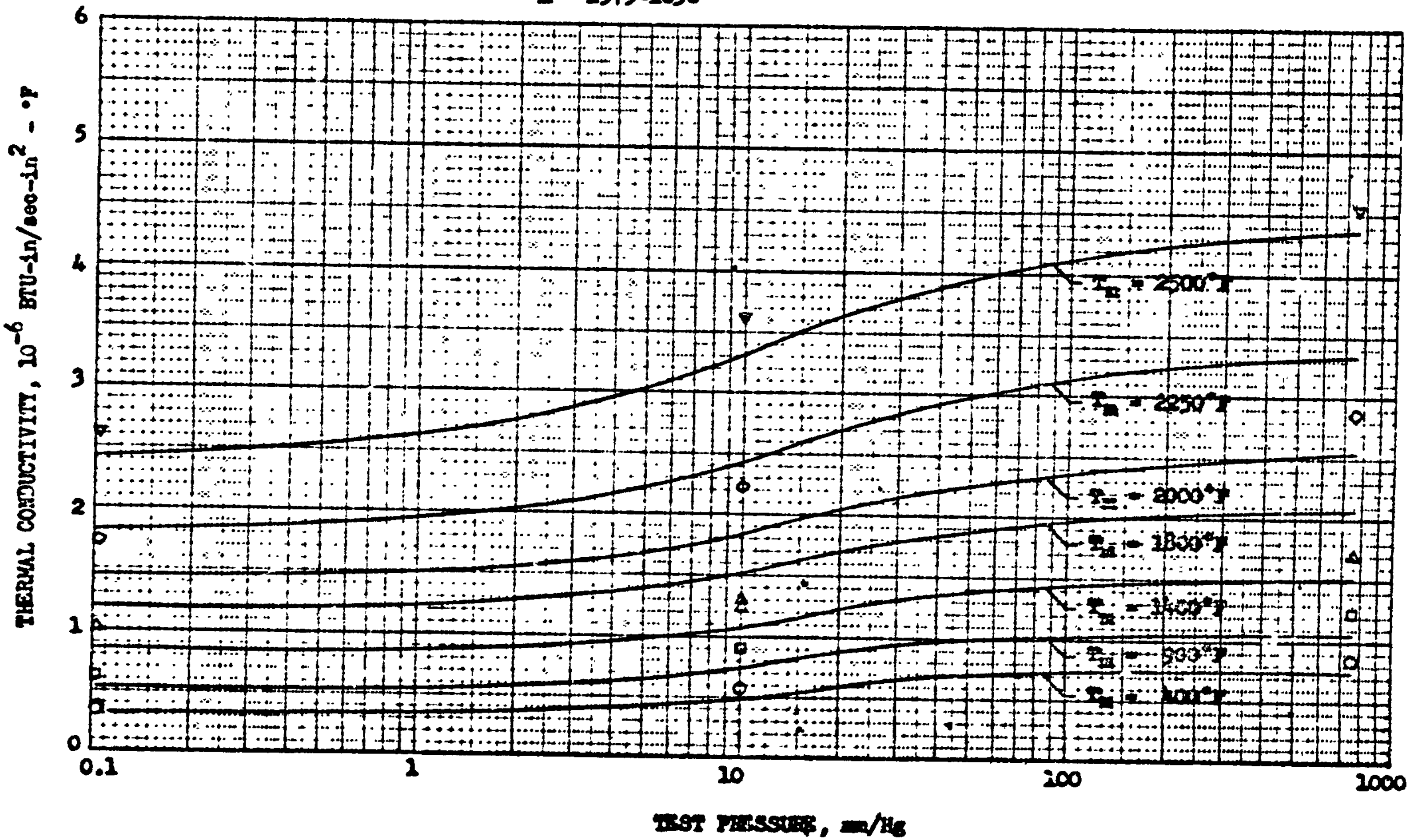


FIGURE A-16

TEMPERATURE EFFECT ON 4.95 LB/FT^3 THERMALLY STABILIZED Q-FELT

Test Pressure = 760 mm/Hg

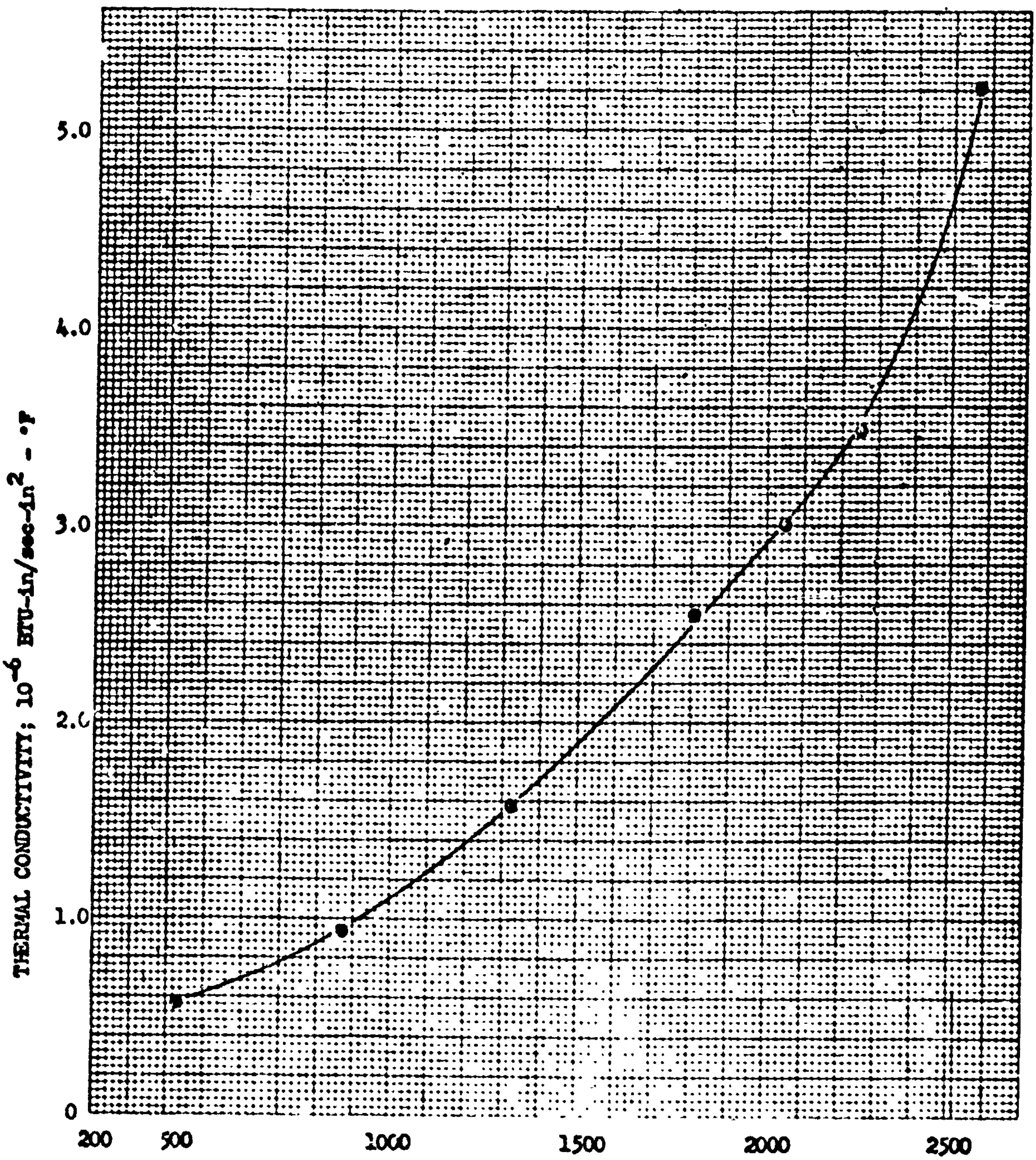


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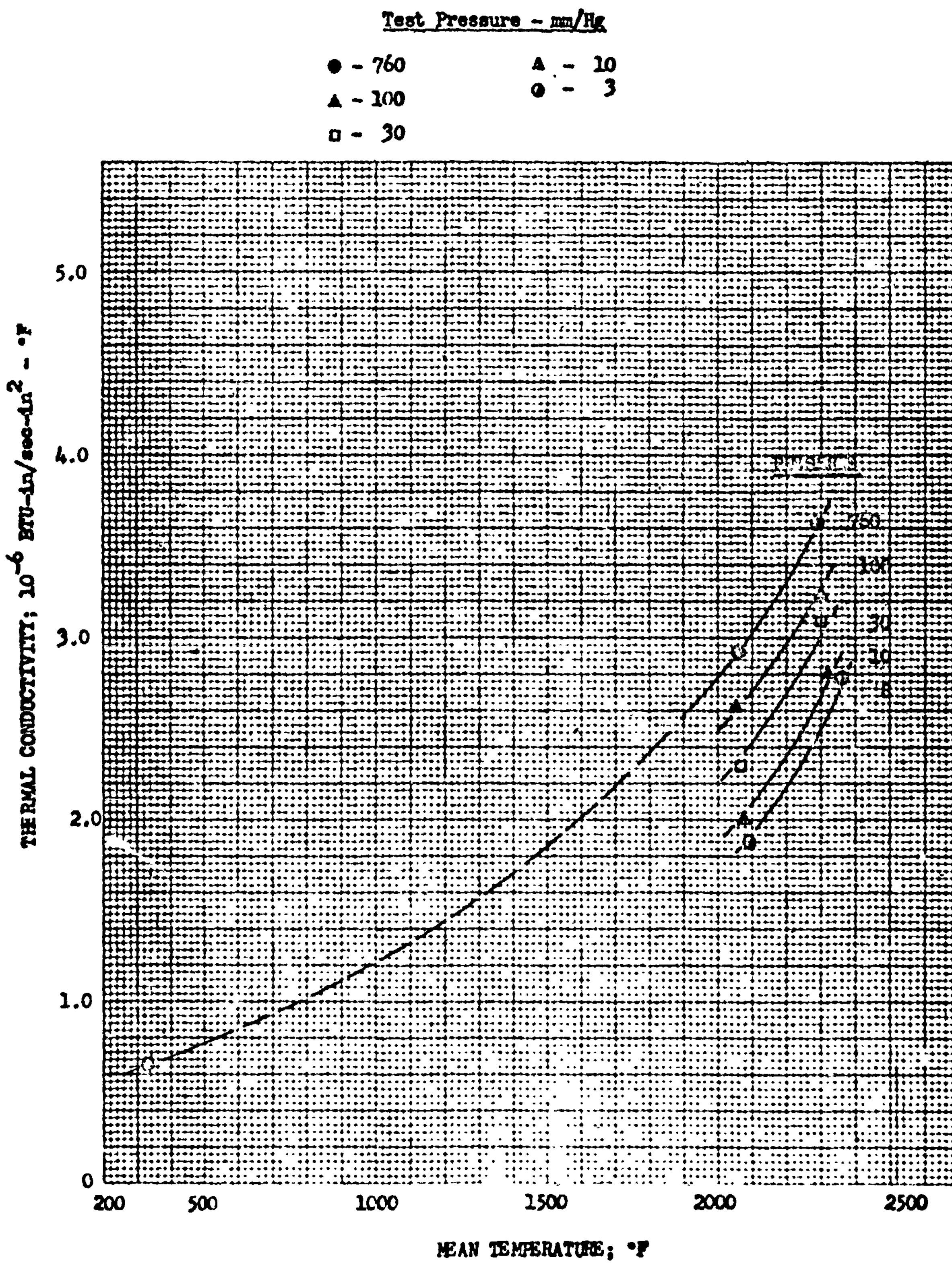
FIGURE A-17

TEMPERATURE EFFECT ON 5.84 LB/FT^3 THERMALLY STABILIZED Q-FELT



2-3532- -08

FIGURE A-18

PRESSURE EFFECT ON 5.84 LB/FT^3 THERMALLY STABILIZED Q-FELT

Mean Test Temperature, °F

□ 2056-2092
○ 2290-2360

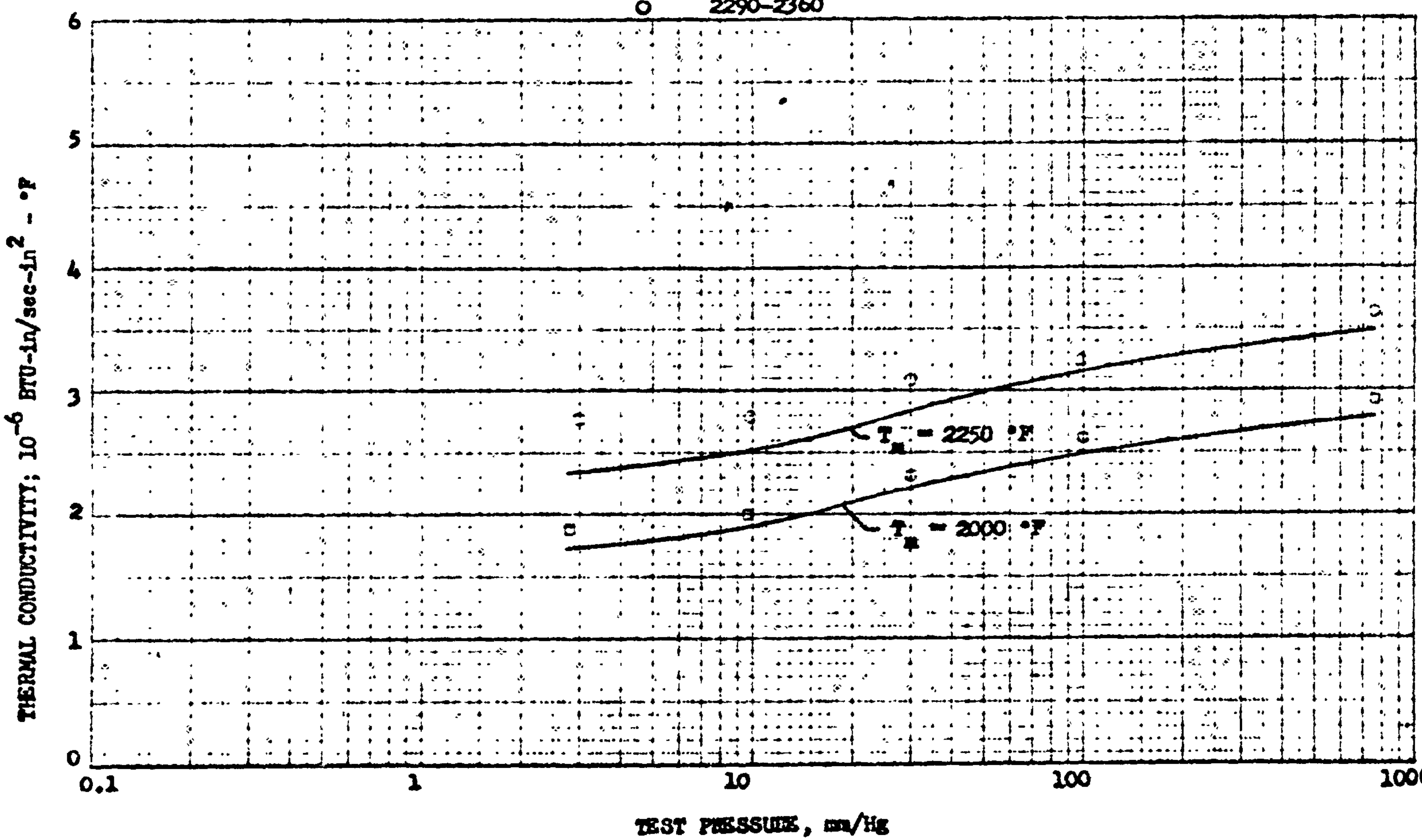
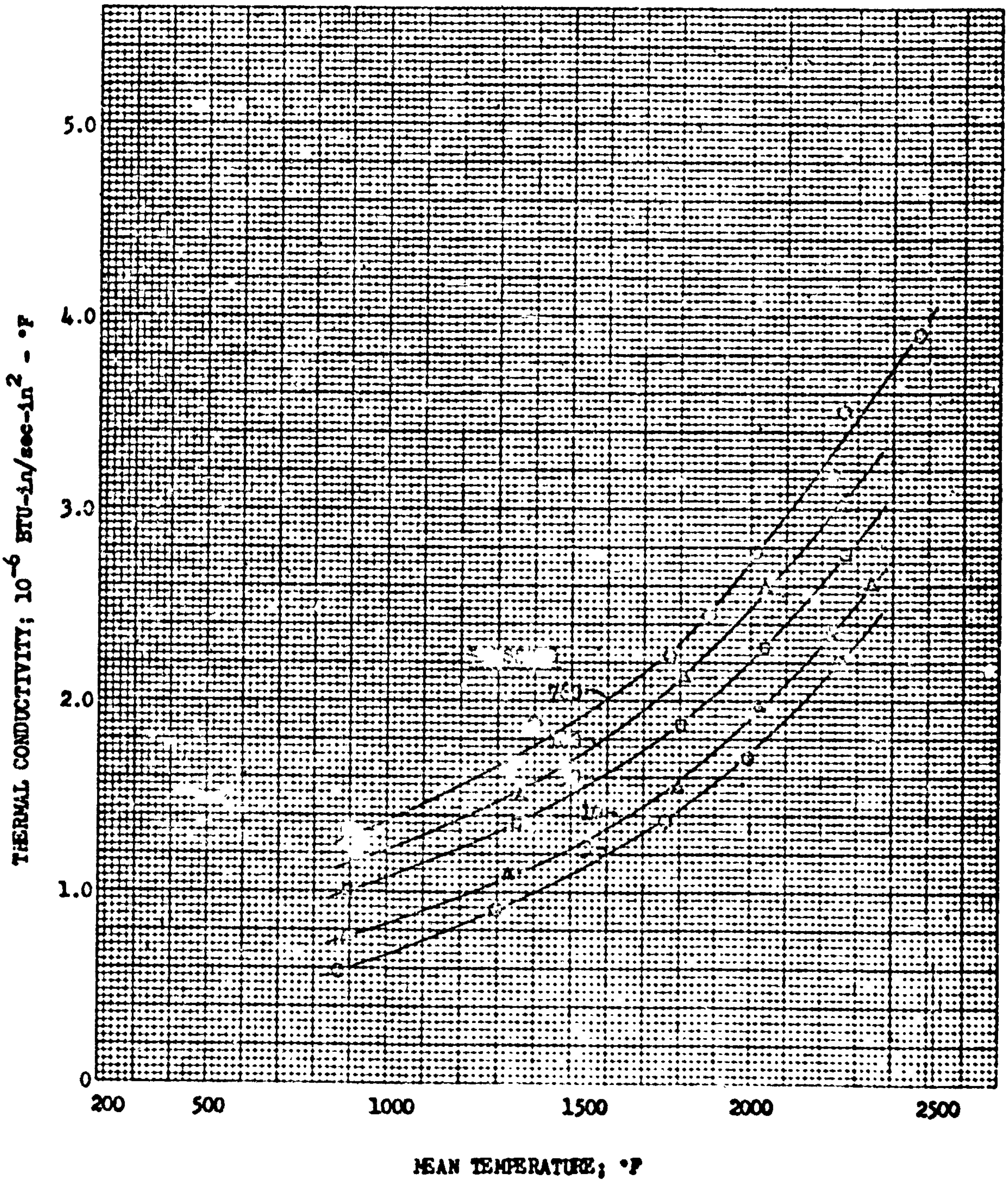


FIGURE A-19

TEMPERATURE EFFECT ON 6.21 LB/FT^3 THERMALLY STABILIZED Q-FELT

Test Pressure - mm/Hg

● - 760 ▲ - 10
▲ - 100 ⊙ - 3
□ - 30



2-3592-1-08

FIGURE A-20

PRESSURE EFFECT ON 6.21 LB/FT^3 THERMALLY STABILIZED Q-FELT

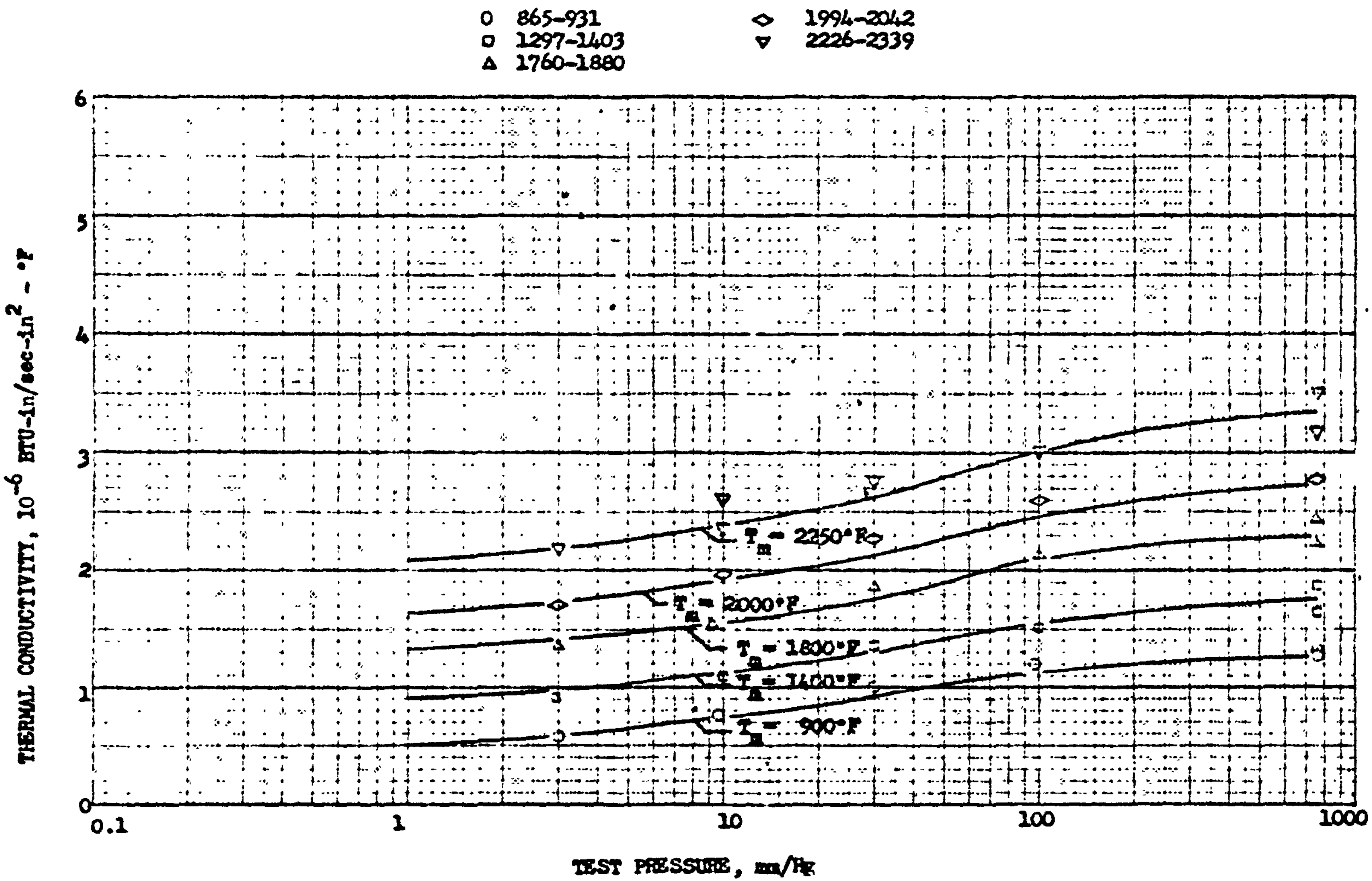


FIGURE A-21

TEMPERATURE EFFECT ON 6.34 LB/FT^3 THERMALLY STABILIZED Q-FELT

Test Pressure = 760 mm/Hg

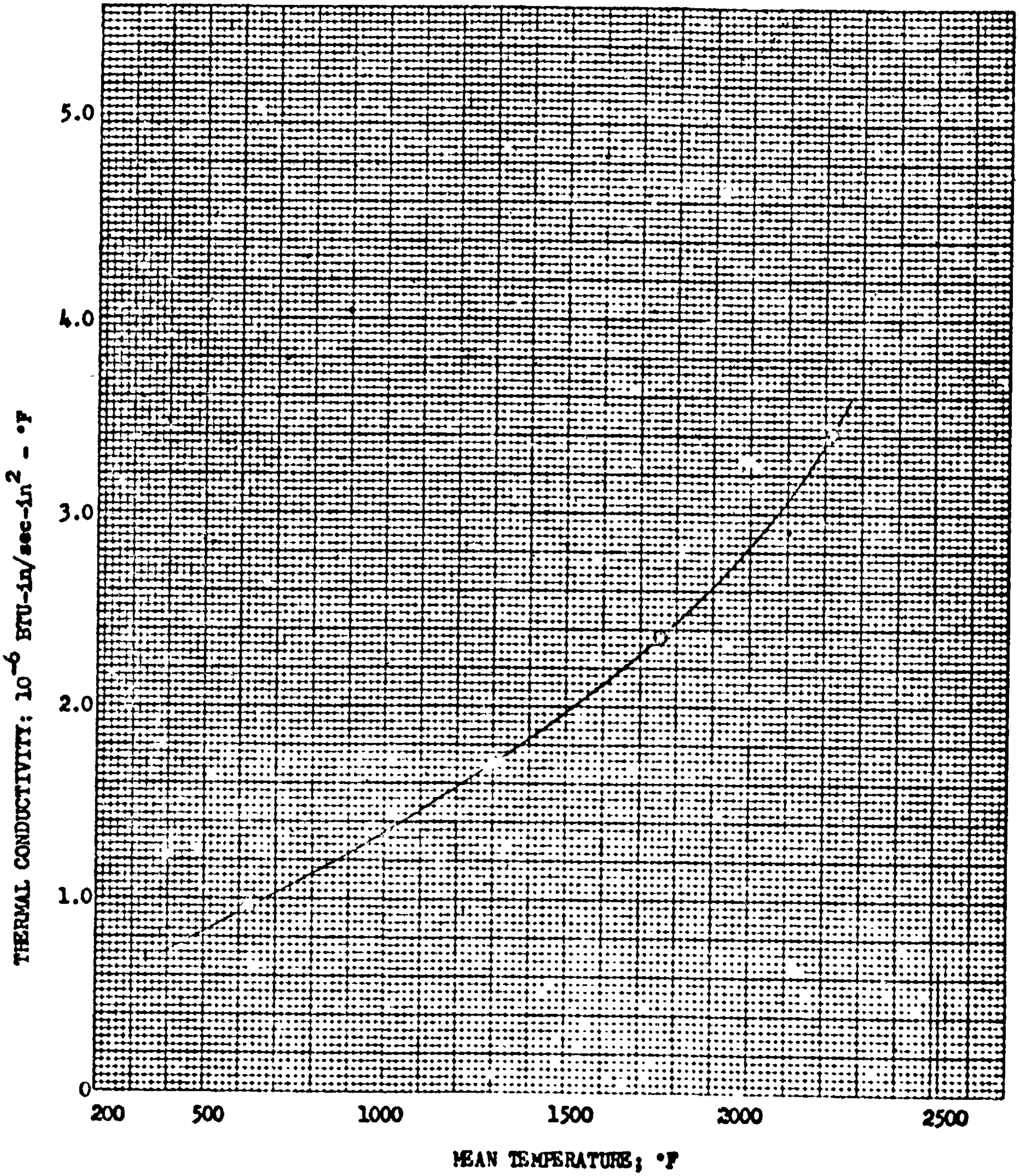


FIGURE A-22

TEMPERATURE EFFECT ON 8.0 LB/FT^3 THERMALLY STABILIZED Q-FELT

Test Pressure - mm/Hg

● - 760   ■ - 5
□ - 30   ○ - 1

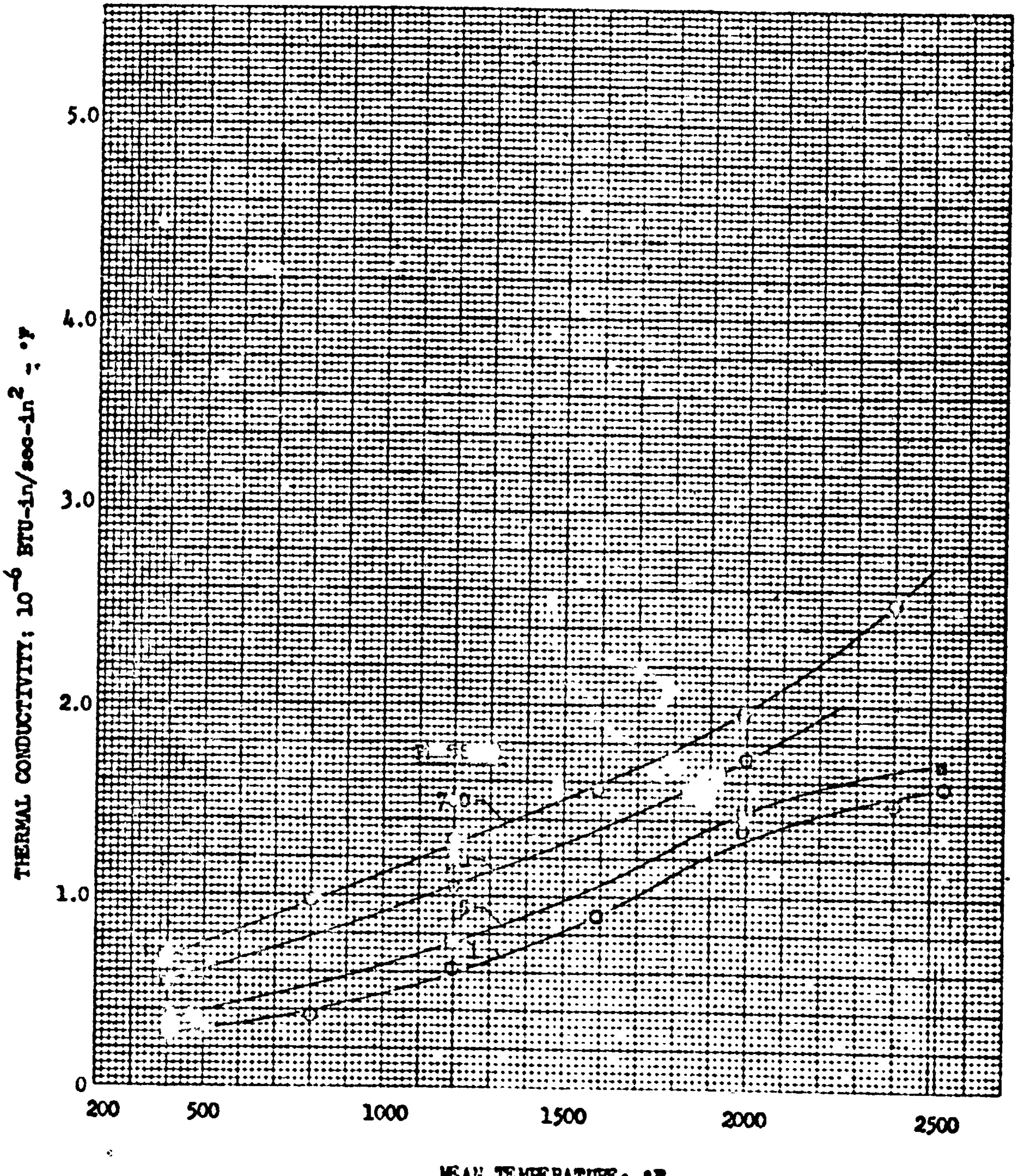


FIGURE A-23

PRESSURE EFFECT ON 8.0 LB/FT^3 THERMALLY STABILIZED Q-FELT

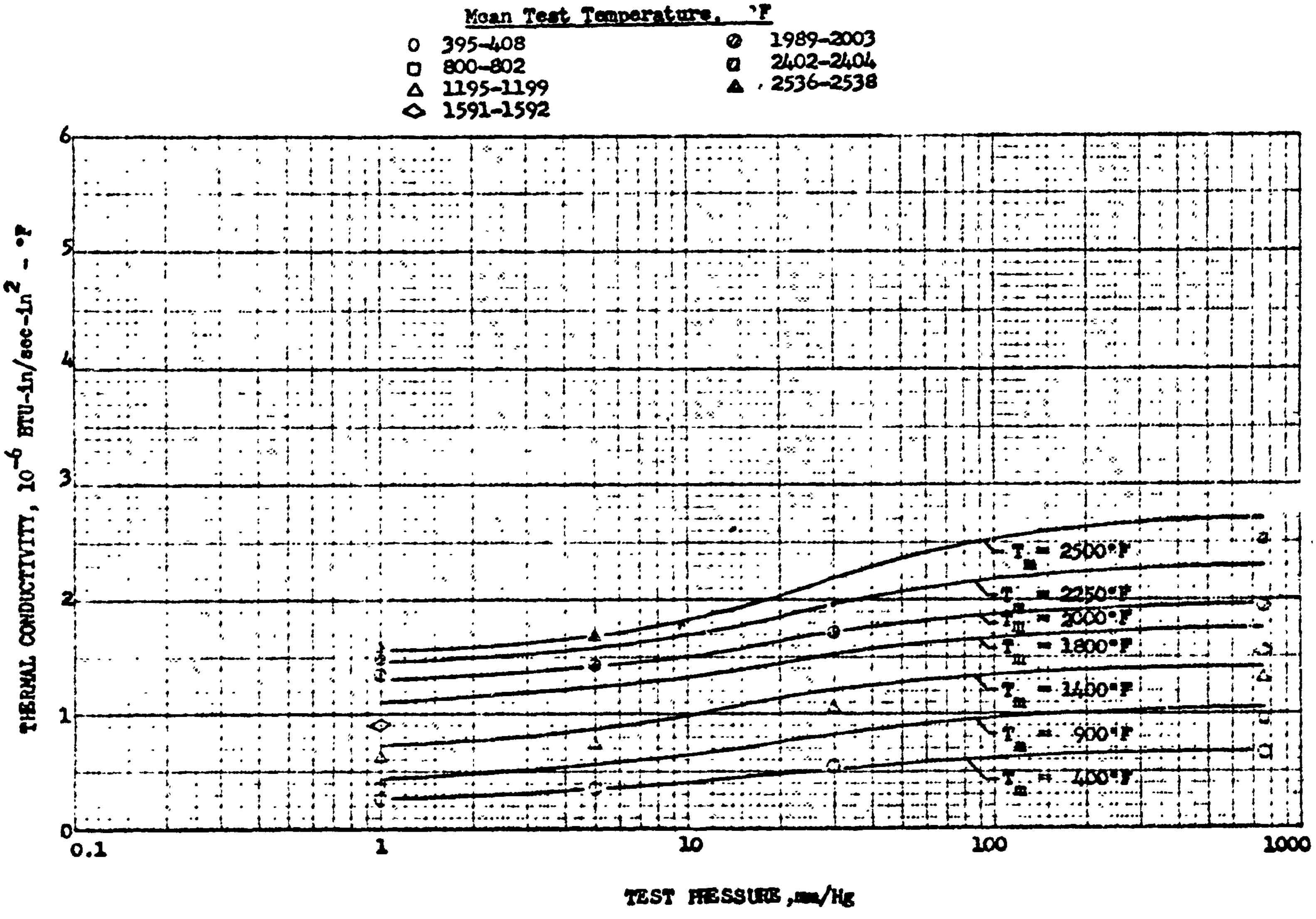
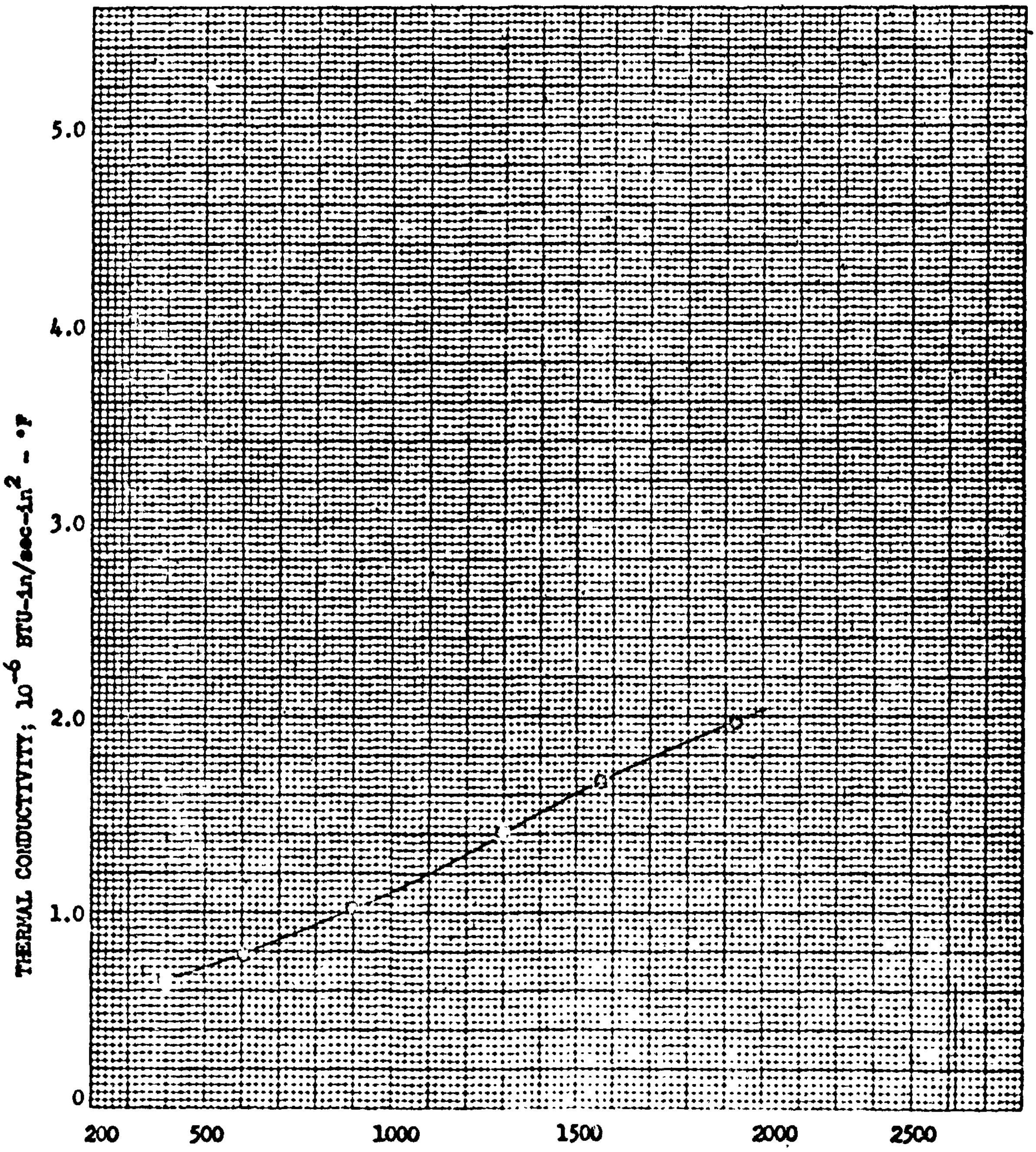


FIGURE A-24

TEMPERATURE EFFECT ON 10.8 LB/FT^3 THERMALLY STABILIZED Q-FELT

Test Pressure = 760 mm/Hg



APPENDIX B

TABULATED TEST DATA

The actual test data obtained in this test program is provided in tabular form in this appendix Each table presents the data obtained on a particular lot of material. The tabulated data is included for the convenience of those wishing to review the actual test data.

Tables B-1 through B-8 show the data for the unstabilized material. Tables B-9 through B-14 includes the thermally stabilized test data. The tables are arranged in order of increasing specimen density for each material condition.

TABLE B-1

TEST DATA FOR 3.55 TO 4.06 LB/FT^3 UNSTABILIZED Q-FELT FROM LOT D

Test Apparatus: Heat Flow Transducer

Thermal Stabilization Treatment	Specimen Density lb/ft^3	Test Pressure MM/HG	Specimen Thickness t - in.	Test Temperatures - °F: Hot Face T_H	Cold Face T_C	Mean T_M	ΔT (T_H-T_C)	Q $\frac{10^{-6} BTU}{sec-in^2}$	K $\frac{10^{-6} BTU-in}{sec-in^2-°F}$
none	3.55	760	.50	400	300	350	100	153	.76
				800	626	713	174	422	1.21
				1200	967	1084	233	816	1.75
				1500	1228	1364	272	1215	2.23
	3.55	760	.50	1800	1502	1651	298	1722	2.89
	3.58	760	.50	400	298	349	102	155	.76
				800	621	710	179	422	1.18
				1200	958	1079	242	812	1.68
				1500	1220	1360	280	1206	2.15
	3.58	760	.50	1800	1495	1648	305	1730	2.83
	3.78	760	.50	400	291	346	109	141	.65
				798	615	706	183	384	1.05
				1200	964	1082	236	750	1.59
				1502	1244	1373	258	1117	2.16
	3.78	760	.50	1800	1508	1654	292	1568	2.68
	3.76	760	.50	400	292	346	108	143	.66
				800	623	712	177	384	1.08
				1200	966	1083	234	745	1.59
				1500	1230	1365	270	1109	2.05
	3.76	760	.50	1800	1510	1655	290	1572	2.71
	4.06	760	.50	400	300	350	100	159	.79
				400	300	350	100	168	.84
				800	627	714	173	455	1.31
				1200	972	1086	228	861	1.89
				1500	1230	1365	270	1281	2.37
none	4.06	760	.50	1800	1505	1652	295	1823	3.09

TABLE B-2

TEST DATA FOR 3.68 AND 3.75 UNSTABILIZED Q-FELT FROM LOT E

Test Apparatus: Heat Flow Transducer

Thermal Stabilization Treatment	Specimen Density lb/ft^3	Test Pressure MM/HG	Specimen Thickness t - in.	Test Temperatures - °F Hot Face T_H	Cold Face T_C	Mean T_M	ΔT (T_H-T_C)	Q $\frac{10^{-6} BTU}{sec-in^2}$	K $\frac{10^{-6} BTU-in}{sec-in^2-°F}$
None	3.68	760	.50	400	290	345	110	153	.69
				400	288	344	112	150	.67
				800	610	705	190	417	1.09
				1200	940	1070	260	785	1.51
				1500	1200	1350	300	1163	1.94
	3.68	760	.50	1800	1462	1631	338	1668	2.47
	3.75	760	.50	395	284	339	111	153	.69
				400	288	344	112	155	.69
				800	612	706	188	426	1.13
				1200	948	1074	252	806	1.60
				1500	1205	1352	295	1191	2.02
None	3.75	760	.50	1800	1484	1642	316	1707	2.70

TABLE B-3

TEST DATA FOR 3.6 LB/FT^3 UNSTABILIZED Q-FELT

Test Apparatus: Heat Flow Transducer

Thermal Stabilization Treatment	Specimen Density lb/ft^3	Test Pressure MM/HG	Specimen Thickness t - in.	Test Temperatures - °F: Hot Face T_H	Cold Face T_C	Mean T_M	ΔT $(T_H - T_C)$	Q 10^{-6} BTU/sec-in^2	K 10^{-6} BTU-in/sec-in^2-°F
None	3.6	760	.50	490	366	428	124	210	.85
		100		490	412	451	78	131	.84
		50		490	418	454	72	120	.83
		20		490	420	455	70	108	.77
		10		490	412	451	78	111	.71
		5.0		490	400	445	[illegible]	98	.54
		1.0		490	388	439	102	94	.46
		0.50		485	338	412	147	89	.30
		0.20		495	330	412	165	90	.27
		0.10	.50	495	330	412	165	89	.27
		760	.50	1000	808	904	192	572	1.49
		100		1000	865	932	135	414	1.53
		20		1000	865	932	135	355	1.31
		5.0		1000	828	914	172	331	.96
		1.0		1000	795	898	205	324	.79
		0.50		1000	786	893	214	322	.75
		0.20		1000	776	888	224	319	.71
		0.10	.50	1000	785	892	215	324	.75
		760	.50	1505	1255	1375	250	1134	2.27
		100		1500	1305	1402	195	880	2.25
		100		1500	1308	1404	192	880	2.29
		20		1500	1296	1398	204	789	1.93
		5.0		1500	1260	1380	240	760	1.58
		1.0		1500	1234	1367	266	773	1.45
		0.50		1500	1228	1364	272	779	1.43
		0.20		1500	1225	1362	275	766	1.39
		0.10	.50	1500	1225	3162	275	744	1.35
		760	.50	2000	1698	1849	302	2035	3.37
		100		2000	1745	1872	255	1653	3.24
		20		1995	1725	1860	270	1505	2.79
		5.0		1990	1680	1835	310	1448	2.33
		1.0		1985	1656	1820	329	1485	2.25
		0.50		1990	1656	1823	334	1470	2.20
		0.20		1990	1660	1825	330	1439	2.18
None	3.6	0.10	.50	1985	1658	1822	327	1398	2.14

TABLE B-4

TEST DATA FOR 3.7 LB/FT^3 UNSTABILIZED Q-FELT

Test Apparatus: Guarded Hot Plate

Thermal Stabilization Treatment	Specimen Density lb/ft^3	Test Pressure MM/HG	Specimen Thickness t - in.	Mean Temperature °F	K $\frac{10^{-6} BTU-in}{sec-in^2-°F}$
None	3.7	760	.50	340	.71
↓	↓	↓	↓	440	.82
None	3.7	760	.50	550	.91

TABLE B-5

TEST DATA FOR 4.3 LB/FT^3 UNSTABILIZED Q-FELT

Test Apparatus: Infinite Cylinder

Thermal Stabilization Treatment	Specimen Density lb/ft^3	Test Pressure MM/HG	Specimen Thickness t - in.	Test Temperatures - °F Hot Face T_H	Cold Face T_C	Mean T_M	ΔT $(T_H - T_C)$	Q $\frac{10^{-6}\,BTU}{sec\text{-}in^2}$	K $\frac{10^{-6}\,BTU\text{-}in}{sec\text{-}in^2\text{-}°F}$
None	4.3	760	.50	350	260	305	90	127	.70
				599	471	535	128	240	.94
				1060	860	960	200	620	1.55
				1475	1205	1340	270	1187	2.20
None	4.3	760	.50	1750	1430	1590	320	1630	2.54

TABLE B-6

TEST DATA FOR 5.1 LB/FT^3 UNSTABILIZED Q-FELT

Test Apparatus: Heat Flow Transducer

Thermal Stabilization Treatment	Specimen Density lb/ft^3	Test Pressure MM/HG	Specimen Thickness t - in.	Test Temperatures - °F: Hot Face T_H	Cold Face T_C	Mean T_M	ΔT $(T_H - T_C)$	Q $\frac{10^{-6} BTU}{sec\text{-}in^2}$	K $\frac{10^{-6} BTU\text{-}in}{sec\text{-}in^2\text{-}°F}$
None	5.1	760	.50	500	365	432	135	195	.72
		100		500	407	454	93	131	.70
		20		500	405	452	95	108	.57
		5.0		500	379	440	121	96	.40
		1.0		500	331	416	169	80	.24
		0.50		500	315	408	185	76	.20
		0.20		500	302	401	198	72	.18
		0.10	.50	500	302	401	198	70	.18
		760	.50	1008	779	894	229	534	1.16
		100		1002	824	913	178	386	1.08
		20		1005	814	910	191	334	.87
		5.0		1000	760	880	240	301	.63
		1.0		1005	714	860	291	283	.48
		0.50		1000	704	852	296	280	.47
		0.20		1002	700	851	302	274	.45
		0.10	.50	1002	700	851	302	268	.44
		760	.50	1510	1205	1358	305	1051	1.72
		100		1510	1252	1381	258	823	1.59
		20		1495	1215	1355	280	710	1.27
		5.0		1498	1158	1328	340	677	.99
		1.0		1498	1122	1310	376	644	.85
		0.50		1502	1116	1309	386	650	.84
		0.20		1500	1120	1310	380	667	.88
		0.10	.50	1500	1120	1310	380	654	.86
		760	.50	1993	1645	1819	348	1846	2.65
		100		1981	1668	1824	313	1486	2.37
		20		1984	1622	1804	363	1377	1.89
		5.0		1985	1600	1792	385	1240	1.61
		1.0		1985	1530	1758	455	1273	1.40
		0.50		1980	1522	1751	458	1265	1.38
		0.20		1982	1526	1754	456	1204	1.32
None	5.1	0.10	.50	1982	1530	1756	452	1169	1.29

TABLE B-7

TEST DATA FOR 7.3 LB/FT^3 UNSTABILIZED Q-FELT

Test Apparatus: Heat Flow Transducer

Thermal Stabilization Treatment	Specimen Density lb/ft^3	Test Pressure MM/HG	Specimen Thickness t - in.	Test Temperatures - °F: Hot Face T_H	Cold Face T_C	Mean T_M	ΔT (T_H-T_C)	Q 10^{-6} BTU / sec-in^2	K 10^{-6} BTU-in / sec-in^2-°F
None	7.3	760	.50	497	368	432	129	201	.78
		300		500	391	446	109	161	.74
		100		496	401	448	95	127	.67
		20		496	396	446	100	104	.52
		5.0		495	355	425	140	84	.30
		1.0		500	293	396	207	66	.15
		0.50		500	276	388	224	63	.14
		0.20		500	266	383	234	60	.13
		0.10	.50	503	262	382	241	57	.12
		760	.50	1000	775	888	225	517	1.15
		760		992	766	879	226	544	1.20
		300		995	796	896	199	453	1.14
		100		990	808	899	182	381	1.05
		20		985	786	886	199	318	.80
		5.0		1000	735	868	265	284	.53
		1.0		998	656	827	342	242	.35
		0.50		1000	645	822	355	240	.34
		0.20		998	640	819	358	235	.33
		0.10	.50	998	637	818	361	231	.32
		760	.50	1505	1200	1352	305	1034	1.69
		760		1490	1168	1329	322	1053	1.63
		300		1490	1206	1348	284	912	1.60
		100		1495	1215	1355	280	810	1.44
		20		1510	1222	1366	288	714	1.24
		20		1495	1170	1332	325	684	1.05
		5.0		1495	1089	1297	406	612	.75
		1.0		1486	1040	1263	446	577	.65
		0.50		1490	1038	1264	452	576	.64
		0.20		1495	1035	1265	460	566	.61
		0.10	.50	1495	1038	1265	457	552	.60
		760	.50	2007	1650	1828	357	1829	2.56
		100		2007	1678	1842	329	1505	2.28
		20		2005	1620	1812	385	1285	1.67
		20		1980	1595	1788	385	1319	1.71
		5.0		2012	1539	1776	473	1169	1.23
		5.0		1985	1500	1742	485	1171	1.21
		1.0		1985	1450	1718	535	1153	1.08
		0.50		1990	1444	1717	546	1136	1.04
		0.20		1990	1435	1712	555	1098	.99
None	7.3	0.10	.50	1985	1435	1710	550	1061	.96

TABLE B-8

TEST DATA FOR 7.5 LB/FT^3 UNSTABILIZED Q-FELT

Test Apparatus: Heat Flow Transducer

Thermal Stabilization Treatment	Specimen Density lb/ft^3	Test Pressure MM/HG	Specimen Thickness t - in.	Test Temperatures - °F: Hot Face T_H	Cold Face T_C	Mean T_M	ΔT (T_H-T_C)	Q $\frac{10^{-6} BTU}{sec-in^2}$	K $\frac{10^{-6} BTU-in}{sec-in^2-°F}$
None	7.5	760	.50	270	137	203	133	178	.67
		30		260	139	200	121	122	.50
		5.0		294	141	217	153	73	.24
		1.0	.50	283	137	210	146	36	.12
		760	.50	776	410	593	366	725	.99
		760	.50	1135	866	1001	269	652	1.21
		30		1128	876	1002	252	419	.83
		5.0		1157	820	989	337	330	.49
		1.0	.50	1196	799	998	397	283	.35
		760	.50	1558	1262	1410	296	1117	1.89
		1.0	.50	1617	1160	1388	457	577	.63
		30	.50	1990	1588	1789	402	1331	1.65
		5.0		2049	1586	1818	463	1223	1.32
None	7.5	1.0	.50	2040	1575	1808	465	1097	1.18

TABLE B-9

TEST DATA FOR 4.95 LB/FT^3 THERMALLY STABILIZED Q-FELT

Test Apparatus: Heat Flow Transducer

Thermal Stabilization Treatment	Specimen Density lb/ft^3	Test Pressure MM/HG	Specimen Thickness t - in.	Test Temperatures - °F: Hot Face T_H	Cold Face T_C	Mean T_M	ΔT $(T_H - T_C)$	Q $\frac{10^{-6} BTU}{sec\text{-}in^2}$	K $\frac{10^{-6} BTU\text{-}in}{sec\text{-}in^2\text{-}°F}$
2200°F 3 hrs	4.95	760	.425	504	356	430	148	199	.57
				1003	733	868	270	598	.94
				1500	1149	1324	351	1306	1.58
				2012	1610	1811	402	2409	2.55
				2263	1833	2048	430	3065	3.03
				2473	2021	2247	452	3704	3.48
2200°F 3 hrs	4.95	760	.425	2769	2358	2564	411	5044	5.21

TABLE B-10

TEST DATA FOR 5.84 LB/FT^3 THERMALLY STABILIZED Q-FELT

Test Apparatus: Heat Flow Transducer

Thermal Stabilization Treatment	Specimen Density lb/ft^3	Test Pressure MM/HG	Specimen Thickness t - in.	Test Temperatures - °F: Hot Face T_H	Cold Face T_C	Mean T_M	ΔT $(T_H - T_C)$	Q 10^{-6} BTU / sec-in^2	K 10^{-6} BTU-in / sec-in^2-°F
2200°F 3 hrs	5.84	760	.355	375	291	333	84	155	.65
		760		2252	1865	2058	387	3179	2.91
		100		2248	1865	2056	383	2830	2.62
		30		2264	1869	2067	395	2567	2.31
		9.7		2270	1883	2076	387	2178	2.00
		2.8		2268	1917	2092	351	1862	1.88
		760		2488	2092	2290	396	4049	3.63
		98		2494	2101	2298	393	3584	3.24
		30		2488	2115	2302	373	3248	3.09
		9.8		2504	2140	2322	364	2866	2.79
2200°F 3 hrs	5.84	3.0	.355	2526	2194	2360	332	2606	2.78

TABLE B-11

TEST DATA FOR 6.21 LB/FT^3 THERMALLY STABILIZED Q-FELT

Test Apparatus: Heat Flow Transducer

Thermal Stabilization Treatment	Specimen Density lb/ft^3	Test Pressure MM/HG	Specimen Thickness t - in.	Test Temperatures - °F: Hot Face T_H	Cold Face T_C	Mean T_M	ΔT $(T_H - T_C)$	Q $\frac{10^{-6} BTU}{sec\text{-}in^2}$	K $\frac{10^{-6} BTU\text{-}in}{sec\text{-}in^2\text{-}°F}$
2250°F 2½ hrs	6.21	760	.33	1010	852	931	158	609	1.27
		760		1006	770	888	236	941	1.31
		96.5		1023	824	923	199	723	1.20
		30.0		997	797	897	200	611	1.01
		9.6		1010	771	891	239	552	.76
		3.0	.33	1002	728	865	274	486	.58
		760	.33	1510	1295	1403	215	1225	1.88
		760		1507	1161	1334	346	1717	1.63
		100		1509	1209	1359	300	1375	1.51
		30.0		1509	1202	1356	307	1265	1.36
		10.0		1502	1154	1328	348	1148	1.09
		2.95	.33	1491	1102	1297	389	1074	.91
		760	.33	2020	1740	1880	280	2077	2.45
		760		1989	1557	1773	432	2924	2.23
		100		2007	1620	1813	387	2504	2.13
		30.0		2005	1601	1803	404	2297	1.87
		9.2		2021	1568	1794	453	2137	1.55
		3.0	.33	2000	1520	1760	480	1991	1.37
		760	.33	2245	1786	2016	459	3869	2.78
		100		2250	1833	2042	417	3279	2.59
		30.0		2257	1821	2039	436	3017	2.28
		10.0		2257	1783	2020	474	2832	1.97
		3.0	.33	2250	1737	1994	513	2654	1.71
		760	.33	2405	2058	2232	347	3347	3.18
		760		2439	2028	2258	461	4911	3.51
		100		2475	2027	2251	448	4099	3.02
		30.0		2506	2036	2271	470	3945	2.77
		10.0		2481	1970	2226	511	3646	2.35
		3.0	.33	2525	1977	2251	548	3646	2.19
		760	.33	2728	2224	2476	504	5980	3.91
2250°F 2½ hrs	6.21	10.0	.33	2602	2075	2339	527	4167	2.61

TABLE B-12

TEST DATA FOR 6.34 LB/FT^3 THERMALLY STABILIZED Q-FELT

Test Apparatus: Heat Flow Transducer

Thermal Stabilization Treatment	Specimen Density lb/ft^3	Test Pressure MM/HG	Specimen Thickness t - in.	Test Temperatures - °F: Hot Face T_H	Cold Face T_C	Mean T_M	ΔT (T_H-T_C)	Q $\frac{10^{-6}BTU}{sec-in^2}$	K $\frac{10^{-6}BTU-in}{sec-in^2-°F}$
2250°F	6.34	760	.33	700	565	632	135	276	.67
2½ hrs				700	565	632	135	395	.96
				1410	1187	1298	223	1153	1.70
				1900	1618	1759	282	2016	2.36
2250°F 2½ hrs	6.34	760	.33	2390	2050	2220	340	3510	3.41

TABLE B-13

TEST DATA FOR 8.0 LB/FT^3 THERMALLY STABILIZED Q-FELT

Test Apparatus: Heat Flow Transducer

Thermal Stabilization Treatment	Specimen Density lb/ft^3	Test Pressure MM/HG	Specimen Thickness t - in.	Test Temperatures - °F: Hot Face T_H	Cold Face T_C	Mean T_M	ΔT (T_H-T_C)	Q $\frac{10^{-6} BTU}{sec\text{-}in^2}$	K $\frac{10^{-6} BTU\text{-}in}{sec\text{-}in^2\text{-}°F}$
2250°F 3 hrs	8.0	760	.25	440	350	395	90	242	.67
				886	713	800	173	671	.97
				1321	1076	1199	245	1276	1.30
				1755	1429	1592	326	2030	1.56
				2182	1797	1989	385	3008	1.95
		760		2546	2262	2404	284	2861	2.52
		30		450	347	398	103	222	.54
				1328	1071	1199	257	1080	1.05
		30		2125	1882	2003	243	1673	1.72
		5		463	353	408	110	162	.37
				1325	1065	1195	260	775	.74
				2171	1809	1990	362	2080	1.43
		5		2746	2326	2536	420	2845	1.69
		1		452	354	403	98	105	.27
				886	719	802	167	250	.37
				1313	1080	1196	233	581	.62
				1736	1446	1591	290	1048	.90
				2156	1828	1992	328	1786	1.36
				2595	2210	2402	385	2301	1.49
2250°F 3 hrs	8.0	1	.25	2747	2330	2538	417	2645	1.58

TABLE B-14

TEST DATA FOR 10.8 LB/FT^3 THERMALLY STABILIZED Q-FELT

Test Apparatus: Infinite Cylinder

Thermal Stabilization Treatment	Specimen Density lb/ft^3	Test Pressure MM/HG	Specimen Thickness t - in.	Test Temperatures ~ °F Hot Face T_H	Cold Face T_C	Mean T_M	ΔT (T_H-T_C)	Q $\frac{10^{-6} BTU}{sec-in^2}$	K $\frac{10^{-6} BTU-in}{sec-in^2-°F}$
2250°F 2 hrs	10.8	760	.20	450	346	398	104	336	.64
				680	530	605	150	585	.78
				1030	760	895	270	1380	1.02
				1490	1114	1302	376	2647	1.41
				1790	1340	1565	450	3755	1.67
2250°F 2 hrs	10.8	760	.20	2190	1666	1928	524	5155	1.97

APPENDIX C

MATERIAL SPECIFICATION, BMS 9-1

High Temperature Mineral Fiber Insulation

A copy of the material specification prepared to provide procurement control of the high temperature mineral fiber insulation, Q-felt is provided in this appendix. This specification was prepared to provide a more uniform product and prevent high temperature reactions due to impurities in the product.

1. SCOPE

This specification covers mineral fiber materials intended for thermal insulation of structures exposed to extremely high temperature environments.

2. REFERENCES

The issue of the following references in effect on the date of invitation for bid shall form a part of this specification to the extent indicated herein.

a. ASTM C 167-50, Standard Method of Test for Thickness and Density of Blanket or Batt Type Thermal Insulating Material

b. Fiberglass Industry Test Method, Procedure for Checking Average Diameter of Glass Fiber in the Williams Freeness Tester

3. TYPES

The material shall be mineral fiber insulation material composed of silicon dioxide (SiO_2) fibers.

3.1 Type I Unstabilized

Type I unstabilized material shall be soft and flexible. The maximum exposure temperature of this type should not exceed 1900F.

3.2 Type II - Heat Stabilized

Type II heat stabilized material is obtained by shrinkage of the Type I material upon thermal treatment at elevated temperatures. After thermal treatment the Type II material shall be dimensionally stable and shall meet such requirements of Section 5. as are applicable.

CODE 81205

BY Lyle L Jones 11-15-63
CHECKED R.B. Underhill
ENGINEERING R Underhill for W.T. Dworshak
QUAL CONTROL Keith [illegible]
MATERIAL [illegible]

HIGH TEMPERATURE MINERAL FIBER INSULATION

BOEING MATERIAL SPECIFICATION

BMS 9-1C

4. FORM

The material shall be supplied in the forms specified in Section 4.1.a and 4.1.b.

4.1 Structure

The blanket and sheet material shall be composed of interlaced fibers which meet the diameter requirements specified in Section 5.2.

a. Type I material shall be supplied in the form of flexible, flat sheets.

b. Type II material shall be supplied in the form of non-flexible sheets.

4.2 Sizes

The normal weight per square foot or density along with the desired dimensions shall be specified on the purchase order. Data for purchasing information is as listed below:

	DIMENSIONS				
	Maximum Length (In.)	Maximum Width (In.)	Minimum Thickness (In.)	Nominal Weight (Lbs/ft²)	Nominal Density (Lbs/ft³)
I	120	30	0.125	0.032	3.0
3	120	30	0.1875	0.047	3.0
2	120	40	0.500	0.146	3.5
II	14	12	0.250	0.094	4.5
	14	12	0.250	0.129	6.2
1	14	12	0.250	0.167	8.0

1 At the present time, the material is commercially available in the sizes listed. If other thicknesses or different material weights are desired, it must be established that the supplier can produce the material which will meet the engineering requirements.

2 Greater thicknesses result in felted blankets with variations of density in the thickness plane.

3 Sheet linear dimensions are limited by manufacturing methods and practical handling and shipping sizes.

5. MATERIAL REQUIREMENTS

The requirements of this Section shall apply to all materials unless otherwise specified.

5.1 Quality

The material shall be of uniform quality, composition, weight per square foot, thickness, and shall contain no shot or any foreign contaminants.

5.2 Fiber Diameter

The material shall be composed of fibers, 0.75 to 1.5 microns average diameter, as determined by the Williams Freeness Test.

5.3 Chemical Composition

The material shall be fibers composed of a minimum of 98.5 weight percent silicon dioxide (SiO_2). The amounts of impurities shall not exceed the following:

IMPURITY	WEIGHT PERCENT Max. Allowed**
Boron (as B)	0.01
Iron (as Fe)	0.06
Aluminum Oxide (Al_2O_3)	0.50
Magnesium Oxide (MgO)	0.35
Calcium Oxide (CaO)	0.35
Sodium Oxide (Na_2O)	0.15
*Total - All other impurities	0.08*

*NOTE: If the total of all other impurities, determined by difference between 100% and the sum of silica and all allowed impurities is higher than 0.08 weight percent, further qualification will be necessary. In this case, the material to be acceptable must then pass the requirements as established in Section 5.5.2.a or 5.5.2.b.

**"Maximum Allowed" applies to the maximum amount found in any single determination.

5.4 Dimensional Stability "Type II"

a. Measurements of thicknesses used to determine compliance with this Section shall be made as specified in Section 6.2.4.

5.4 (Continued)

b. Measurements of linear dimensions used to determine compliance with this Section shall be made to the nearest 0.01 inch unless otherwise specified.

c. No more than 1% dimensional shrinkage shall be allowed after the material is subjected to a thermal treatment of 2750F ± 25F for 1/2 hour.

d. The heating and cooling rate shall be slow enough to prevent excessive warpage of the sample. Heating rate to 2750F is not specified other than to prevent warpage of the samples.

5.5 Surface Contamination and Density Identification

5.5.1 Color

a. Type I

Material shall be white or very light buff in color. The presence of surface discolorations (yellow, red, pink) totaling more than 5% of the total surface area of any sheet shall be cause for rejection of that sheet of material.

b. Type II

To readily distinguish between the three densities of Type II material (4.5, 6.2 or 8.0 lb/ft^3), one surface of the 4.5 lb/ft^3 and 8.0 lb/ft^3 materials shall be colored. The coloring shall burn off at a low temperature, 250 - 1000F, without leaving a residue which will react with the insulation when it is heated to 2750 ± 25F and held for 30 minutes. The insulation shall be within the density tolerances as specified in Section 5.6.1.a both before and after aplication of the coloring dye.

The following formulation is recommended:

50 ml - methyl ethyl ketone

0.02 grams dye - "Calco Aviation Oil Blue," Calco Chemical Divisions, American Cyanamid Company

Dissolve the dye in the ketone and then spray apply to one surface of the insulation as required for the applicable density as listed below. Air dry for 15 - 30 minutes followed by drying for 1 hour at 150 - 180F.

5.5.1.b (Continued)

The Type II material shall be color coated as follows:

(1) 4.5 Lb/Ft^3 Density (Striped)

The 4.5 lb/ft^3 material shall be a white material with blue stripes on one surface. The blue stripes shall be approximately 1/4" wide on 1" centers, shall extend from one end of the sheet to the other, and shall run parallel to the 14" sheet dimension.

(2) 6.2 Lb/Ft^3 Density (White)

The 6.2 lb/ft^3 material shall be the natural white color.

(3) 8.0 Lb/Ft^3 Density (Solid Blue)

One surface (12" x 14" plane) of the 8.0 lb/ft^3 material shall be colored completely with the blue color.

5.5.2 Glass Formation Or Softening -

a. Type I

The Type I material shall not exhibit any indication of softening or glossy formation on any surface after being subjected to the thermal treatment of Section 6.1.1.

b. Type II

Type II material shall not have any areas indicative of glass formation or having softened during the stabilization process used to convert the material into the Type II classification. No sign of softening or glass formation shall be visible on any surface after subjecting the stabilized material to the additional thermal cycles per Section 5.4.c.

5.6 Material Weight, Thickness, Strength and Sampling

5.6.1 Weight

a. Tolerance for the weight per square foot and/or density of material based on the overall sheet size as specified on the purchase order shall be as specified below:

TYPE	Thickness (In.)	Weight (Lbs/Ft^2)	Density (Lbs/Ft^3)
I	0.125 Min.	0.032 ± 0.003	3.0
	0.1875 Min.	0.047 ± 0.005	3.0
1	0.500 Min.	0.146 ± 0.015	3.5
II	$0.250 \begin{smallmatrix} +0.010 \\ -0.00 \end{smallmatrix}$	0.094	4.5 ± 0.25
	$0.250 \begin{smallmatrix} +0.010 \\ -0.000 \end{smallmatrix}$	0.129	6.2 ± 0.5
2	$0.250 \begin{smallmatrix} +0.010 \\ -0.000 \end{smallmatrix}$	0.167	8.0 ± 0.5

1 Minimum thickness and weight per square foot are controlling values. Density is listed for information only.

2 Thickness and density are controlling values. Weight per square foot is listed for information only.

b. The weight per square foot of any three randomly selected 12" x 12" samples, each from a different sheet of the Type I material, shall also be within the tolerances above as allowed for its ordered thickness.

c. Weight per square foot of the Type I material shall be determined as specified in Section 6.1.3.

5.6.2 Thickness

The thickness of the material when determined per Section 6.1.4 or 6.2.4, as applicable, shall be within the tolerances listed in Section 5.6.1.a.

5.6.3 Density

The density of the Type II material when determined per Section 6.2.3 shall be within the applicable tolerance as specified in Section 5.6.1.a.

5.6.4 Flexural Strength

The minimum value of the strength of the Type II material when tested as specified in Section 6.2.5 shall be 12 lbs/in^2.

NOTE: Due to limited test results available at the present time, the value above may have to be adjusted at a later date.

5.6.5 Sampling

To determine compliance with the requirements of Section 5.6, a random sample of 3 sheets or blankets shall be tested from each receival lot.*

* A receival lot shall be defined as the material of one thickness, received by the purchaser at one time, from one production lot of basic fibers.

NOTE: Purchase orders must include sufficient material (in excess of that required) to allow for this sample plan.

6. TEST METHODS

The following test methods shall be used for product acceptance testing done by the purchaser's Quality Control Department.

6.1 Type I Unstabilized Material

6.1.1 Glass Formation Or Softening Of Type I.

To check for the presence of impurities which may cause softening and/or glass formation when the Type I material is subjected to elevated temperatures, the following procedure shall be used:

a. Three randomly selected specimens, 6" x 6", shall be taken from each of the three sampled sheets or blankets.

b. Heat the specimens to 2200F (-0F, +50F) and hold at this temperature for 4 hours. The furnace should not be over 250F at the time the material is placed in it. The rate of heating and cooling shall be slow enough to prevent excessive warpage of the sample. (A suggested heating and cooling rate 50 to 55F per minute to a temperature of 1500F; from 1500F to 2200F at a rate of 10 to 20F per minute - cool at a rate no faster than 400F per hour down to 500F).

6.1.1 (Continued)

c. The specimen shall be placed so that the material is not exposed to direct radiation from the heating elements of the furnace. In addition, there shall be a free flow of air below the supporting platform and over the top surface of the specimen arrangements as indicated in Figure 1.

d. The supporting platform shall consist of a material such as zirconium oxide or iron-free 99% pure aluminum oxide. This material shall not react with the insulation at elevated temperatures.

e. The temperature shall be measured by a Pt, Pt. -Rh., thermocouple placed under a specimen as shown in Figure 1. At least one thermocouple per shelf shall be employed.

f. After cooling, visually inspect the specimen and check for the presence of softening or glass formation.

6.1.2 Color

Visual examination of all surfaces for conformance to requirements of Section 5.5.1 shall be made. Areas which are of questionable color in regard to meeting the requirements may be verified by submitting to the thermal cycle in Section 6.1.1. Indications of softening or glass formation shall then require rejection of that sheet of material.

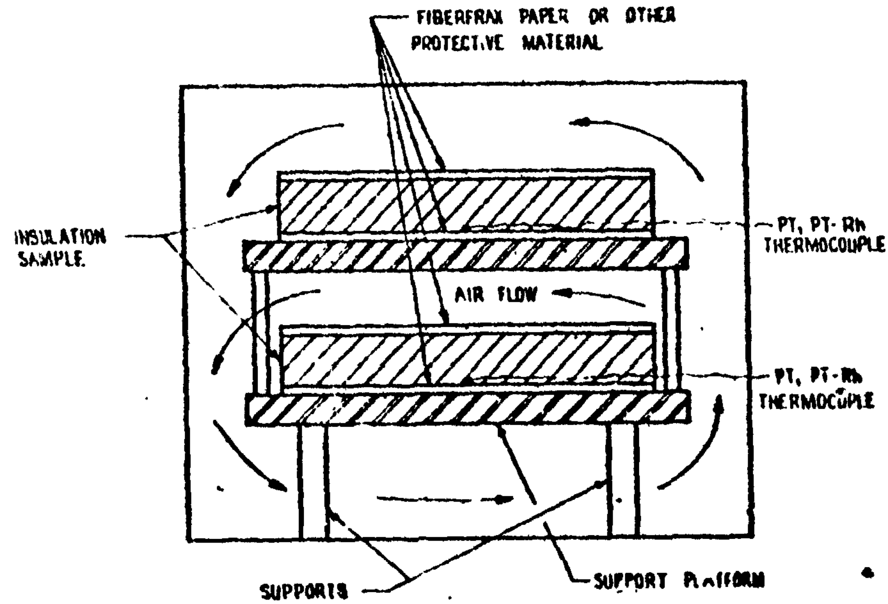


FIGURE 1
ARRANGEMENT OF INSULATION FOR THERMAL TREATMENT

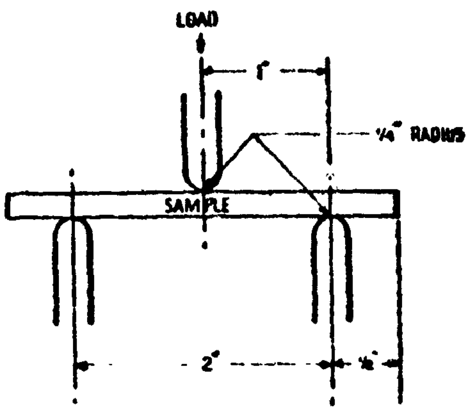


FIGURE 2
FLEXURAL TEST OF TYPE II STABILIZED INSULATION

6.1.3 Average Weight Per Square Foot

a. To determine compliance with the applicable requirements of Section 5.6.1.a, the sheet size as specified shall be weighed to the nearest 10 grams. The linear dimensions of the sheet shall be determined to the nearest 0.1 of an inch. Calculations and determination of conformance to Section 5.6.1 shall then be made from those measurements.

b. To determine compliance with Section 5.6.1.b a randomly selected 12" x 12" sample shall be cut from each of 3 sheets of material. The selection of the sheet material shall also be done in a random manner. The linear dimensions shall be taken to the nearest 0.1 inch and the sample weighed to the nearest 1.0 gram.

c. The average weight per square foot shall be calculated from the following formula:

$$\text{Lbs/sq. foot} = \frac{\text{Weight (grams)} \times 0.317}{\text{Area (square inches)}}$$

6.1.4 Thickness

The test specimen shall be placed on a rigid plate and the thickness measured using a modified ASTM C 167-50 thickness tester. The modification shall be such that the disk be a minimum of 5 inches in diameter. In addition, the total weight of disk shall be adjusted to produce a uniform load of 0.05 lbs/in^2 on the insulation when the disk is freely resting on the material. Measurements shall be taken to the nearest 0.010 inch and the value used shall be the average of all measurements taken. The number of measurements shall not be less than 4 for 12" x 12" and smaller samples, and not less than 8 for the larger sheet size.

6.2 Type II Stabilized Material

6.2.1 Dimensional Stability

a. Test samples, 4" x 4", shall be measured for dimensions per Sections 5.4 and 6.2.4 and then heated to 2750F ± 25F and held for 30 minutes. After cooling and remeasurement of the sample no change of dimensions greater than 1 percent shall be allowed. The heating and cooling rate shall be slow enough to prevent excessive warpage of the test specimen.

b. Positioning of the Type II test samples shall be the same as specified in Section 6.1.1.c through 6.1.1.e.

6.2.2 Color and Surface Contamination

a. Visual examination of the Type II material shall be used to determine compliance to the color requirements as specified in Section 5.5.1.b.

b. Visual examination of the Type II material shall be used to check for the presence of foreign material and/or surface contaminants to insure that the material meets the requirements of Section 5.1 and Section 5.5.2.b.

6.2.3 Density

To determine conformance to the applicable density requirements as specified in Section 5.6.1.a, the following procedures shall be used:

a. Measurements (length and width) of the ordered sheet size shall be taken to the nearest 0.1 inch.

b. At least 4 random measurements of thickness shall be taken as specified in Section 6.2.4. The average value of these measurements shall be used.

c. The weight of the sheet for which the dimensional measurements were taken shall be determined to the nearest 1.0 gram.

d. Calculations of the density shall be made using the values obtained in Sections 6.2.3.a through 6.2.3.c. Density shall be computed using the following formula:

$$\text{Density (lbs/cu.ft.)} = \frac{\text{Wt. (grams)} \times 3.81}{\text{Vol. (cubic inches)}}$$

6.2.4 Dimensions

a. Thickness of the Type II material shall be measured to the nearest 0.001 inch, unless otherwise specified.

b. Length and width of Type II material, after the thermal treatment at 2750F, shall be measured to the nearest 0.01 inch.

c. A minimum of 4 random measurements shall be made on each sample measured, using an appropriate tool. Care shall be taken not to compress the material, so that accurate measurements can be made.

6.2.5 Flexural Strength

a. Flexural strength testing of the Type II material to determine compliance to Section 5.6.4 shall be done on a minimum of three samples per sheet of material. The number of sheets tested shall be as specified, per Section 5.6.5.

b. The test setup shall be as shown by Figure 2 with a load rate of 0.5 in./minute. The support and loading members shall be at least 3 inches wide. The test sample dimensions shall be 3.0 ± 0.030 inch by 3.0 ± 0.030 inch.

c. All values obtained shall be equal to or greater than the minimum value specified in Section 5.6.4. Values shall be expressed in pounds per square inch and calculated using the following formula:

$$F_s = \frac{3Pl}{2bd^2}$$

Where: F_s = Flexural Strength in lbs/in^2

P = Applied load in lbs.
l = Span between supports in inches
b = Width of specimen in inches
d = Thickness of specimen in inches

Dimensional measurements shall be made to the nearest 0.01 inch.

7. QUALITY CONTROL

7.1 Supplier

Suppliers shall furnish a statement indicating conformance to Sections 5.1, 5.5.2 and test data showing conformance with Sections 5.2 and 5.3 with each shipment.

7.2 Purchaser

The purchasers Quality Control shall perform any of the tests of this specification necessary to insure that materials conform to the requirements of this specification.

In addition, Quality Control shall test each receival lot to the requirements of Sections 5.4 5.5 and 5.6.1 as is applicable to the type of material received.

8. PACKAGING AND MARKING

a. Packaging shall be such as to assure safe delivery.

b. Each package shall be durably and legibly marked with the following information:

(1) Boeing Material Specification Number BMS 9-1C and Type number.

(2) Boeing Purchase Order Number.

(3) Suppliers Lot Number

NOTE: Different Lot Number Designation must be assigned to materials produced from different production batches of basic fibers.

(4) Suppliers Date of Manufacture (Date felt manufactured).

(5) Suppliers Material Designation.

(6) Quantity.

c. Type II non-flexible sheet, 4.5 lb/ft^3 and 8.0 lb/ft^3 density, shall be color coated one side per Section 5.5.1.b.

9. REJECTION

If the results of any test made upon a sample do not conform to the requirements stated in this specification, the material shall be rejected.